TRANSACTIONS

OF THE

AMERICAN SOCIETY

OF

MECHANICAL ENGINEERS.

VOL. XXIII.

XLIVTH MEETING, NEW YORK, N. Y., 1901.
XLVTH MEETING, BOSTON, MASS., 1902.

G. R. Brandon

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OFFICERS

OF THE

AMERICAN SOCIETY OF MECHANICAL ENGINEERS,

1901–1902,

FORMING THE STATUTORY COUNCIL.

PRESIDENT.

EDWIN REYNOLDS .... Milwaukee, Wis.

VICE-PRESIDENTS.

ARTHUR M. WAITT .... New York, N. Y.
JAMES M. DODGE .... Philadelphia, Pa.
AMBROSE SWASEY .... Cleveland, Ohio.
Terms expire at Annual Meeting of 1902.

WILFRED M. LEWIS .... Philadelphia, Pa.
M. E. COOLEY .... Ann Arbor, Mich.
M. P. HIGGINS .... Worcester, Mass
Terms expire at Annual Meeting of 1903.

MANAGERS.

FRANCIS H. BOYER .... Somerville, Mass.
JOHN A. BRASHEAR .... Allegheny, Pa.
ALFRED H. RAYNAL .... Washington, D. C.
Terms expire at Annual Meeting of 1902.

W. F. M. GOSS .... Lafayette, Ind.
DE COURCY MAY .... Camden, N. J.
D. S. JACOBUS .... Hoboken, N. J.
Terms expire at Annual Meeting of 1903.

R. S. MOORE .... San Francisco, Cal.
H. A. GILLIS .... Richmond, Va.
CHAS. H. CORBETT .... Brooklyn, N. Y.
Terms expire at Annual Meeting of 1904.

TREASURER.

WM. H. WILEY .... Nos. 43–45 East 19th St., New York, N. Y.

SECRETARY.

PROF. F. R. HUTTON .... No. 12 West 31st St., New York, N. Y.

HONORARY COUNCILLORS.

Past Presidents of the Society.

R. H. Thurston	1880—1882	Ithaca, N. Y.
E. D. Leavitt	1882—1883	Cambridgeport, Mass.
John E. Sweet	1883—1884	Syracuse, N. Y.
Coleman Sellers	1885—1886	Philadelphia, Pa
Horace See	1887—1888	New York City.
Henry R. Towne	1888—1889	Stamford, Conn.
Oberlin Smith	1889—1890	Bridgeton, N. J.
Robert W. Hunt	1890—1891	Chicago, Ill.
Charles H. Loring	1891—1892	Brooklyn, N. Y.
Charles E. Billings*	1895	Hartford, Conn.
John Fritz	1895—1896	Bethlehem, Pa.
Worcester R. Warner	1896—1897	Cleveland, Ohio.
Charles Wallace Hunt	1897—1898	New York City.
George W. Melville	1898—1899	Washington, D. C.
Charles H. Morgan	1899—1900	Worcester, Mass.
S. T. Wellman	1900—1901	Cleveland, Ohio.

[Note.—The former Presidents of the Society are members of the Council for life or during their retention of active membership in the Society.]

* Unexpired term of E. F. C. Davis.

NOTE.

The considerable bulk of the volume of Transactions has induced the Publication Committee to direct the insertion of a summary of the Society membership in place of the complete list of members which was published in the earlier volumes. The summary attaching to this issue is that which appears in the catalogue of the Society issued with corrections to July, 1902. Reference for the complete list should be made to the twenty-third catalogue issued on that date.

The summary is as follows :

FOREIGN COUNTRIES.

	Membership.		Membership.
Africa	15	Holland	1
Australia	5	India	1
Belgium	3	Jamaica, W. I.	1
Canada	21	Japan	6
Central America	1	Mexico	6
China	2	Norway	1
Cuba	5	Russia	7
France	9	South America	8
Germany	9	Sweden	3
Great Britain (England)	45	Switzerland	1
" " (Scotland)	3		

Total foreign membeiship 153

UNITED STATES.

	Membership.		Membership.
Alabama	4	Montana	10
Alaska	1	Nebraska	2
Arizona	1	New Hampshire	16
Arkansas	3	New Jersey	126
California	28	New Mexico	1
Colorado	25	New York	660
Connecticut	98	North Carolina	5
Delaware	11	North Dakota	1
District of Columbia	26	Ohio	174
Georgia	7	Oklahoma	1
Illinois	150	Oregon	3
Indiana	32	Pennsylvania	337
Iowa	5	Porto Rico	1
Kansas	3	Rhode Island	50
Kentucky	5	South Carolina	5
Louisiana	8	Tennessee	3
Maine	12	Texas	6
Maryland	29	Utah	4
Massachusetts	220	Vermont	8
Michigan	59	Virginia	24
Minnesota	11	Washington	4
Mississippi	2	West Virginia	7
Missouri	33	Wisconsin	47

Total membership in the United States........2,268

GEOGRAPHICAL SUMMARY.

Total foreign membership	153
Total membership in United States	2,268
Present address unknown *	4
Total membership	2,425

SUMMARY OF MEMBERSHIP BY GRADES.

Honorary members	18
Members	1,667
Associate members	174
Junior members	566
Total membership	2,425
Life members †	106

* These are James W. Miller, J. H. Pendleton, Wm. R. MacDonald, and Chester P. Wilson, and if any member knows their present addresses, he will confer a favor by advising the Secretary of them.

† These Life Members are included in the total membership above, in the class to which they belong.

RULES OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

ART. 1. The objects of the AMERICAN SOCIETY OF MECHANICAL ENGINEERS are to promote the Arts and Sciences connected with Engineering and Mechanical Construction, by means of meetings for social intercourse and the reading and discussion of professional papers, and to circulate, by means of publication among its members, the information thus obtained.

ART. 2. All persons connected with engineering may be eligible for admission into the Society.

ART. 3. The Society shall consist of Honorary Members, Members, Associates, and Juniors.

ART. 4. Honorary Members, not exceeding twenty-five in number, may be elected. They must be persons of acknowledged professional eminence.

ART. 5. To be eligible as a Member, the candidate must be not less than thirty years of age, and must have been so connected with engineering as to be competent as a designer or as a constructor, or to take responsible charge of work in his department, or he must have served as a teacher of engineering for more than five years.

NOTE.—The Rules of the Society, adopted in 1880, were in force until 1884, when they received general revision by a careful committee, whose report, distributed by letter ballot, was adopted November 5, 1884. In December, 1894, a similar extensive revision was made under direction of the Council, and the present rules are those of 1894. They include the amendments made in 1889, 1891, 1893, and 1898, which were the only changes since the revision of 1884.

ART. 6. To be eligible as an Associate the candidate must be not less than twenty-six years of age, and must have the other qualifications of a member; or he shall have been so connected with engineering as to be competent to take charge of work, and to coöperate with engineers.

ART. 7. To be eligible as a Junior, the candidate must have had such engineering experience as will enable him to fill a responsible position, or he must be a graduate of an engineering school.

ART. 8. All Honorary Members, Members, and Associates shall be equally entitled to the privileges of membership. Juniors shall not be entitled to vote, nor to be officers of the Society.

ART. 9. Nominees for Honorary Membership must be proposed by at least five Members who are not officers of the Society. References shall not be required of a nominee for Honorary Membership, but the grounds upon which the application is made must be fully set forth in writing and signed by the proposers.

ART. 10. A candidate for admission to the Society, as a Member or as an Associate, must make an application on a form to be prepared by the Council, which shall contain a written statement giving a complete account of his engineering experience and an agreement that he will, if elected, conform to the laws, rules, and requirements of the Society. He must refer to at least five Members or Associates to whom he is personally known. A candidate for admission to the Society as a Junior must make an application on the same form, and refer to not less than three Members or Associates to whom he is personally known.

Applications for membership from engineers who are not resident in the United States and Canada, and who may be so situated as not to be personally known to five Members of the Society, as required in the foregoing paragraph, may be recommended for ballot by five Members of the Council, after sufficient evidence has been secured which shall show that in their opinion the applicant is worthy of admission to the grade which he seeks.

ART. 11. The referees for each candidate for admission to the Society shall be requested to make a confidential communication on a form to be prepared by the Council, setting forth in detail

such information, personally known by the referee, as shall enable the Council to arrive at a proper estimate of the eligibility of the candidate for admission to the Society. Such confidential communications shall be destroyed by the Secretary as soon as the vote has been officially declared.

Art. 12. All applications for membership must be presented to the Council, and this body shall consider each application, assigning to each, with the applicant's consent, the grade in the Society to which, in its opinion, his qualifications entitle him. The names of those candidates recommended for election by the Society shall be immediately printed on a ballot, and the ballot mailed at once by the Secretary to each voting member of the Society. Persons desiring to change their grade of membership from junior to associate or from associate to member shall make an application in the same manner and on the same form as that required for a new applicant.

Art. 13. A member entitled to vote may leave the name of any candidate on the ballot untouched to vote in favor of the admission of the candidate to the Society, or he may erase the name to vote against it. He shall enclose the ballot so approved by him in a sealed blank envelope, and enclose this envelope in a second envelope, on which he shall write his name, and mail the same to the Secretary of the Society. A ballot without such endorsement shall be rejected as defective. The rejection of a candidate by seven voters shall defeat his election.

Art. 14. The aforesaid envelopes containing the ballots shall be opened by the Council, at any meeting thereof, and the names of those elected shall be announced in the next meeting of the Society. The names of applicants not elected shall not be announced, nor recorded in the proceedings.

Art. 15. Endorsers of any applicant not elected may, within three months after such failure to be elected, lay before the Council written evidence that an error was then made. The Council may then, by a three-fourths vote, order another similar ballot by the Society, in which case thirteen negative votes shall be required to defeat the candidate.

Art. 16. Honorary members shall be elected by the unanimous vote of the Council, through a letter ballot, not less than sixty days subsequent to the proposal, a notice of which proposed election shall have been mailed at once by the Secretary to each member of the Council.

Art. 17. Each person elected, excepting honorary members, must subscribe to the Rules of the Society, and pay the initiation fee before he can receive a certificate entitling him to the rights and privileges of the Society, and to wear the emblem appropriate to his grade. If this payment is not made within six months of the election, the same shall be void, unless the time is extended by the Council. The emblems of each grade of membership shall be worn by those only who belong to that grade.

Art. 18. The initiation fee of a member or an associate shall be twenty-five dollars, and the annual dues shall be fifteen dollars, payable in advance. The initiation fee of a junior shall be fifteen dollars, and his annual dues ten dollars, payable in advance. A junior being promoted to any other grade of membership shall pay an additional initiation fee of ten dollars. Any member or associate may become a Life Member in the same grade, by the payment of two hundred dollars at one time, and shall not be liable thereafter to annual dues.

The Council shall have the power, for special reasons, by unanimous vote, through a letter ballot, to admit to life membership, without the payment of the sum above named, such person as for a long term of years has been a member or an associate, when such a procedure would in its judgment be for the best interests of the Society; *provided*, that notice of such action shall have been given at a previous meeting of the Council.

Art. 19. Any member of the Society in arrears may, at the discretion of the Council, be deprived of the publications of the Society, or, when in arrears for one year, he may be stricken from the list of members. Such person may be restored to the privileges of membership by the Council on payment of all arrears.

Art. 20. The affairs of the Society shall be managed by a Council, consisting of a President, six Vice-Presidents, nine Managers, and a Treasurer, who shall also be the Trustees of the Society.

All past (ex) Presidents of the Society, while they retain their membership therein, shall be known as Honorary Councillors, and shall be entitled to receive notices of all meetings of the Council and may take part in any of its deliberations; they shall be entitled to vote upon all questions except such as affect the legal rights or obligations of the Society or its members.

Art. 21. The members of the Council shall be elected from among the members and associates of the Society at the annual meetings, and shall hold office as follows:

The President and the Treasurer for one year; and no person shall be eligible for immediate re-election as President who shall have held that office for two consecutive years; the Vice-Presidents for two years, and the Managers for three years; and no Vice-President or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected.

Art. 22. A Secretary, who shall be a member of the Society, shall be appointed for one year by a majority of the members of the Council at its first meeting after the annual election, or as soon thereafter as the votes of a majority of the members of the Council can be secured for a candidate. The Secretary may be removed by a vote of twelve members of the Council, at any time after one month's notice has been given him by a majority of its members to show cause why he should not be removed, and he has been heard to that effect. The Secretary may take part in any of the deliberations of the Council, but shall not have a vote therein. His salary shall be fixed for the time he is appointed by a majority vote of the Council.

Art. 23. At each annual meeting, a President, three Vice-Presidents, three Managers, and a Treasurer shall be elected, and the term of office of each shall continue until the end of the meeting at which their successors are elected.

Art. 24. The duties of all officers shall be such as usually pertain to their offices or may be delegated to them by the Council or by the Society. The Council may, in its discretion, require bonds to be given by the Treasurer.

Art. 25. The Council may, by vote of a majority of all its members, declare the place of any officer vacant, on his failure for one year, from inability or otherwise, to attend the Council meetings, or to perform the duties of his office. All such vacancies and those occurring by death or resignation shall be filled by the appointment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed; *provided*, that the said appointment shall not render him ineligible at the next annual meeting.

Art. 26. Five members of the Council shall constitute a quorum. Members of the Council absent from a meeting may vote by letter upon subjects stated in the call for the meeting, said vote to be deposited with the Secretary.

ART. 27. The President on assuming office shall appoint a Finance Committee and a Publication Committee and a Library Committee of five members each. The appointment of two members of each Committee shall expire at the end of each year. The Secretary shall, *ex officio*, be a member of all three committees.

ART. 28. The Finance Committee shall have power to order all ordinary or current expenditures, and shall audit all bills therefor. No bill shall be paid except upon their audit. When special appropriations are ordered by the Society, they shall not take effect until they have been referred to the Council and Finance Committee in conference.

ART. 29. It shall be the duty of the Publication Committee to receive all papers contributed, and to decide upon which papers or parts of the same shall be presented at the professional meetings of the Society. They shall see that all editorial revisions of the proceedings, papers, discussions, and reports are made; and to decide what parts of the same shall be published in the proceedings of the Society. The Council may, at its discretion, revise any action of the Publication Committee.

ART. 30. It shall be the duty of the Library Committee to take charge of the collection of all material for the Library of the Society, and to supervise all regulations for its use.

ART. 31. At the regular meeting preceding the annual meeting a Nominating Committee of five members, not officers of the Society, shall be appointed, and this committee shall, at least thirty days before the annual meeting, send to the Secretary the names of nominees for the offices falling vacant under the rules. In addition to such regularly appointed committee, any other five members or associates, not in arrears, may constitute an independent Nominating Committee, and may present to the Secretary, at least thirty days before the annual meeting, all the names of such candidates as they may select. All the names of such independent nominees shall be placed upon the ballot list, with nothing to distinguish them from the nominees of the regular committee, and the Secretary shall at once mail the said list of names to each member and associate in the form of a letter ballot, it being understood that the assent of the nominees shall have been secured in all cases.

ART. 32. In the election of Vice-Presidents, each member and associate may cast as many votes as there are Vice-Presidents

to be elected. He may give all these votes to one candidate, or distribute them among more, as he chooses. Managers shall be voted for in the same way.

ART. 33. Any member or associate entitled to vote may vote by retaining or changing the names on said list, leaving names not exceeding in number the officers to be elected, and returning the list to the Secretary—such ballot enclosed in two envelopes, the inner one to be blank and the outer one to be endorsed by the voter. No member or associate in arrears since the last annual meeting shall be allowed to vote until said arrears shall have been paid.

ART. 34. The said blank envelopes shall be opened by tellers at the annual meeting, and the person who shall have received the greatest number of votes for the several offices shall be declared elected.

MEETINGS.

ART. 35. The annual meeting of the Society shall be held on the first Tuesday in December of each year, in the City of New York, unless otherwise ordered, at which a report of proceedings and an abstract of the accounts shall be furnished by the Council. The Council may change the place of the annual meeting, and shall, in that case, give timely notice to members and associates.

ART. 36. Other regular meetings of the Society shall be held in each year at such time and place as the Council may appoint. At least thirty days' notice of all meetings shall be mailed by the Secretary to members, honorary members, associates, and juniors.

ART. 37. Special meetings may be called whenever the Council may see fit; and the Secretary shall call a special meeting at the written request of twenty or more members. The notices for special meetings shall state the business to be transacted, and no other shall be entertained.

ART. 38. Any member, honorary member, or associate, may introduce a stranger to any meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

ART. 39. Every question which shall come before the Society shall be decided, unless otherwise provided by these rules, by the votes of a majority of the members and associates present, provided there is a quorum.

Art. 40. At any regular meeting of the Society thirteen or more members and associates shall constitute a quorum.

Art. 41. Unless otherwise ordered, papers shall be read in the order in which their text is received by the Secretary. Before any paper appears in the *Transactions* of the Society, a copy of the paper shall be sent to the author, and, so far as possible, a copy of the reported discussion shall be sent to every member who took part in the same, with requests that attention shall be called to any errors therein.

Art. 42. The Society shall claim no exclusive copyright in papers read at its meetings, nor in reports of discussions, except in the matter of official publication with the Society's imprint, as its *Transactions*. The Secretary shall have sole possession of papers between the time of their acceptance by the Publication Committee and their reading, together with the drawings illustrating the same; and at the time of such reading, or as soon thereafter as practicable, he shall cause to be printed, with the authors' consent, copies of such papers, "subject to revision," with such illustrations as are needed for the *Transactions*, for distribution to the members and for the use of technical newspapers, American and foreign, which may desire to reprint them in whole or in part. The policy of the Society in this matter shall be to give papers read before it the widest circulation possible, with the view of making the work of the Society known, encouraging mechanical progress, and extending the professional reputation of its members.

Art. 43. The author of each paper read before the Society shall be entitled to twelve copies, if printed, for his own use, and all members shall have the right to order any number of reprints of papers at a cost to cover paper and printing; *provided*, that said copies are not intended for sale.

Art. 44. The Society is not, as a body, responsible for the statements of fact or opinion advanced in papers or discussions, at its meetings; and it is understood that papers and discussions should not include matters relating to politics or purely to trade.

Art. 45. These rules may be amended, at any annual meeting, by a two-thirds vote of the members present; *provided*, that written notice of the proposed amendment shall have been given at a previous meeting.

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LIST OF ILLUSTRATIONS.

PAPERS

OF THE

NEW YORK MEETING

(XLIVth)

OF THE

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

DECEMBER 3d TO 6th, 1901.

BEING ALSO THE TWENTY-SECOND ANNUAL MEETING OF THE SOCIETY.

No. 914.

PROCEEDINGS

OF THE

NEW YORK MEETING

(XLIVth)

OF THE

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

December 3d to 6th, 1901.

THE twenty-second annual meeting of the Society, which was also its forty-fourth convention, was held in New York City, at the house of the Society and its Library, No. 12 West Thirty-first Street, opening on Tuesday, December 3d, and adjourning on Friday, December 6, 1901.

The opening session was called to order by the President of the year, Mr. Samuel T. Wellman of Cleveland, at nine o'clock in the evening, who presented his address, entitled "Early History of Open-Hearth Steel Manufacture in the United States," illustrated with diagrams.

The tellers required under Article 34 of the Rules, to open and count the letter ballots cast for officers of the Society, were appointed by the President before adjournment of the meeting. After announcements by the Secretary, a recess was taken until the following morning. A light luncheon was served in the collation room in the basement, and the members remained until a late hour.

SECOND DAY. WEDNESDAY MORNING, DECEMBER 4TH.

The second, or business, session of the annual meeting was called to order in the morning at ten o'clock. Registration of the members in attendance at the meeting had opened early on the

previous day and was continued until the last day of the meeting. The custom was continued, which has proved so successful, of giving each line on the official register a consecutive number and of issuing transcripts from the register, which contained the name and corresponding number. Each button badge worn by the member at the meeting carried the number of the line of the register on which the name was found, so that identification and introduction were made easy and definite. The guests who registered were also requested to give the name of the persons by whom they were introduced. The numbers in attendance at the New York meeting have become so great that a reproduction of the register would be a matter of several pages, and it is omitted from the present record.

The registration of members aggregated 519, and the invited guests brought the total registration up to 745.

The first order of business at the annual meeting was the Report of the Tellers appointed the previous evening to count the ballot for officers. The Secretary read their report as follows:

December 4, 1901.

Your committee, appointed as tellers of election to sort and count the ballots for officers of the American Society of Mechanical Engineers for the year 1901–1902, submit the following report:

Total number of ballots cast	622
" " rejected on account of irregularities	17
" " of ballots counted	605

Of the latter number, votes were counted as follows:

For President.	
Edwin Reynolds	605
For Treasurer.	
William H. Wiley	604
For Vice-Presidents.	
Wilfred Lewis	604
M. E. Cooley	606
M. P. Higgins	602
R. H. Soule	1
For Managers.	
R. S. Moore	602
H. A. Gillis	607
Chas. H. Corbett	602
A. J. Pitkin	1

William T. Bonner,
Horace B. Gale, } *Tellers.*

The President thereupon declared the election of the above-named officers, and asked whether Mr. Edwin Reynolds, President-elect was present in the room, and if he would accept the office to which the Society had elected him. Mr. Reynolds on signifying his acceptance was escorted to the platform by Messrs. Fritz and Swasey, who were appointed a committee of the Council for this purpose. Mr. Wellman then introduced the new President to the Society as his successor, and bespoke for Mr. Reynolds the same courtesy and good will which had been uniformly shown to him during his own term of office.

The Secretary then read the Annual Report of the Council, which was in print, and to which was appended the Report of the Finance Committee of cash transactions of the Society during the year and the Report of the Library Association.

ANNUAL REPORT OF THE COUNCIL.

THE Council would present to the Society, convened for its twenty-second annual meeting, the report of business which has been considered by it, and of action which has been taken during the year.

At the first meeting of the Council for the current Society year, in December, 1900, a special committee of three was ordered who should consider with the secretary the advisability of extending the usefulness of the secretary's office to the Society and its work. As the result of the deliberations of this committee, the Council approved a policy looking to a more active canvass for desirable papers to be read at the meetings, and, further, that certain directions of work should be pursued with more vigor. To carry out these suggestions, it was ordered that an additional assistant should be furnished to the secretary, who should be an educated mechanical engineer, and who should enter the office to supplement the work which has been so effectively done by the staff in the employ of the Society up to this time. The choice for this officer fell upon Mr. Arthur L. Rice, who began his duties just previous to the spring meeting of 1901. It was the opinion of the Council that there were advantages connected with the more frequent issue of the Employers' Bulletin than had hitherto been made, and that there were directions in which the Society's library could be made useful to the members, if there was continuously on duty at the Society

house a person competent to make references, and prepare abstracts and similar work, which could be done at the request of non-resident members in the library of the Society. In the redistribution of responsibility in the secretary's office, certain duties which had grown upon the hands of the Society's accountant were transferred, in order that the necessity for overtime work might be somewhat removed during periods of the Society year when pressure of work is particularly insistent.

The Council has passed resolutions of thanks to the Societies in Great Britain and France, to whose courtesy the Society was indebted during the visit of the American engineers to the Exposition of 1900, and these resolutions have been handsomely illuminated and transmitted to the transatlantic societies. The Council has also expressed to Mr. H. H. Suplee, who acted as a secretary for the committee during the stay of the American engineers in England, a hearty vote of thanks for all that he was enabled to do.

It has been referred to a committee of the Council to consider and formulate a plan for the holding of reunions of members of the Society in the Society House intermediate between the regular semi-annual meetings. This committee has made no definite report at this time by reason of the fact that the action of the committee would necessarily be conditioned upon the action of the Society in the matter of increasing the revenues.

In view of the demand made upon the Society to meet the financial obligation entailed by the installation of the heating and ventilating apparatus, authority was given to the Finance Committee to borrow the necessary money through the usual channels. This step was taken by the committee in the form of paying for the heating apparatus out of the income, and giving a note to the Society's printer for the payment which it had incapacitated itself to make by reason of this expenditure.

The Society has expressed its willingness to coöperate with the Verein Deutscher Ingenieure of Germany in the preparation of a technical dictionary which that body proposes to issue. The offer has been of coöperation in the matter of technical or expert knowledge under the provision that by making this tender the Society assumes no obligations for financial outlay.

The Council has considered a proposition to amend its Rules, whereby a greater proportion of the voting membership should

be required in order to bring about the defeat of a candidate seeking election to membership.. The practice of this Society is at present much more rigid than that of the sister Societies in England or the Continent, in requiring only seven negative votes to defeat an election. The report of a committee of the Council making a recommendation in this direction is lying upon the table of the Council, but has not received favorable action.

The most important subject which has been before the attention of the Council during the current year has been the consideration of the financial problem confronting the Society. An investigation brought about the fact that the average age at which the present eighty-eight life members had taken their life membership would be forty-five years. A trust and annuity company would only give a return of $15 per annum for an investment of $223.44. It was therefore apparent that at $200, the life membership fee was too low if the annual dues were $15. The Council has also considered exhaustively a series of tables representing the expenditure made by the Society per member, and the average receipt in dues from the members of all classes. This investigation developed the fact that the return to the membership from the Society represented a sum in excess of that which they paid for dues. It was, therefore, a question for the Council to consider whether it was the better policy to restrict and reduce the return to members in publications and otherwise, and at the same time to effect a more considerable economy in management, so that the outgo per member should be reduced below the amount received from him, with the attendant lowering of standard in all respects in which the Society makes a return for dues. The other policy, which would obviously be necessary if the Society was to move forward in the matter of its standing before the community and the visible return to members for their expenditure, would involve an increase in the dues which each member was to contribute. It was the unanimous opinion of the Council that the best interests of the Society would be secured by a forward movement rather than by a retrograde. If the Council was to give any consideration to the question of more complete and adequate accommodation for its library and auditorium with the present grade of expenditure, it would obviously be also necessary to increase the return from the membership. In view of

these considerations, after long discussion it was decided to present an amendment to the Rules, which should propose an increase of annual dues in all grades; and under the requirements of the Rules with respect to such amendments, a written notice was presented at the Milwaukee meeting of May, 1901. Later in the year, by direction of the Council, the secretary sent out to all members a circular in the following form:

SUGGESTED INCREASE OF DUES.

DEAR SIR:

The amount of the dues in this Society in its various grades is specified in the Rules, so that any change in the amount in these dues becomes a change in the Rules, and is to be treated according to the provisions of that instrument, which are contained in Article XLV. This article provides that a two-thirds vote of the members present at any annual meeting may order such amendment, provided that written notice of the proposed amendment shall have been given at a previous meeting. In accordance with this provision a written notice was presented at the Milwaukee meeting of May, 1901, that a motion to increase the rate of the annual dues would be presented at the December annual meeting. This circular is issued to give an opportunity for due consideration of the questions involved in such increase in the dues, before the question comes up for a vote in the constitutional way at the annual meeting; the question is considered of sufficient importance to demand that every member should give the necessary attention to it. While a formal letter-ballot is not provided under the Rules, yet an expression of opinion from the entire membership would be a very serviceable guide to the actual voting assembly at the proper time.

The proposed amendment providing an increase in the dues was presented by direction of the Council, after that body had given careful consideration to the broad questions involved in such a measure. It is the opinion of the Council that the fullest presentation should be made of the considerations which have influenced it in giving a favorable sanction to a proposition of this character, both in order that these considerations shall be a matter of record on the one hand, and, furthermore, so that every one may be fully informed. These considerations may be summarized as follows:

I.

The *Transactions* of the Society, bound in an annual volume, constitute the principal return which the greater number of members of the Society receive, whose residence may be at such a point, or whose business may be of such character, as to preclude their active participation in the semi-annual conventions. It is obvious that the wider the range of professional subjects included in this volume, and the higher their grade, the more valuable is this return. A very considerable proportion of the annual dues goes directly to the preparation of this volume, to which must be added a very considerable indirect expense. The printing, the engraving, the paper and press work, binding, the pamphlet copies (printed in advance of the meetings, and the later issue of pamphlets which contain the discussions), are obviously expenses of the direct class. The salary of the secretary and of the required office staff; the fees of the stenographer at the meetings; the rental of convention halls at which the papers are read, at points

outside of New York City, represent expenditure of the indirect class. A careful tabulation of the direct cost of recent volumes, prepared at the request of the Finance Committee, is as follows :

Vol. 18	$6.10	per copy.
Vol. 19	5.14	"
Vol. 20	6.63	"
Vol. 21	6.18	"

The larger size, and therefore the increased cost and value of Volume XXII. for the year 1901, will make its cost proportionately greater than its predecessors, and will raise, therefore, the figure for direct cost. It will be observed that with the present rate of dues for Junior Members ($10), the amount available for the indirect expenses, which are much the greater proportion, is less than one-half the amount of their dues.

II.

It is the wish of the Council that the value to the members of their annual volume of *Transactions* should be increased rather than, that by seeking measures of economy, that return should be diminished. This would appear to be the wiser as well as the more generous policy, because the quality of the *Transactions* determines in a very large part the standing of the Society, both in America and abroad. While the methods of producing the publications of the Society are possibly not the most economical that could be devised, a reduction of cost would be secured by a sacrifice of efficiency. It would be possible to have the papers read at the meetings from manuscript only, instead of having them printed complete in advance and distributed ; if this were done it would not be necessary to pay for the composition of practically the entire half of the volume before the meeting, and keep the type standing until the necessary discussion can be arranged in its proper place in connection with each paper. Or, an economy could be secured by printing the advance copies of the papers, sent to all members at present, in a very much smaller edition, so as to supply only those attending a meeting, and let the rest of the membership wait until the volume could be distributed, as was formerly done. Or, an economy could be effected by diminishing the extent and quality of the illustrations of the papers. Or, the the members could be charged for pamphlets furnished them instead of the present more generous policy of allowing the members to have such small supplies of the various papers as they need for their professional use, without charge. It is the conviction of the Council that a plan for reducing the return to the members in any of these forms would be a step backward, and would not be generally received with favor. It will be apparent, however, from the later dis cussion, that unless the dues are to be raised, some or all of these steps will have to be taken.

III.

The Society has been issuing twice a year its Catalogue and List of Members in two forms at each issue. The semi-annual issue is to enable the Society's list to embody the entire list of additions to the Society at each meeting, by the usual process of election, and, further, to make the catalogue as nearly correct in the matter of addresses as possible. The use of the larger or alphabetical catalogue by the members of the Society who are in business would seem to justify the present method. If, however, an economy is desired, it can be secured by letting the catalogue go for a year, with an appendix after the spring meeting, which shall contain the additions and corrections. Any who have had experience with

this sort of thing will appreciate at once the confusion and awkwardness of it, but the present arrangement is not as economical as the alternative would be. The smaller, or vest-pocket edition has been greatly appreciated by that proportion of the membership who have occasion to make use of their list when travelling and otherwise. If economy must be practised, the issue of the vest-pocket edition could be cut off. The systems of registration at the conventions which have been so much approved have cost much money, and an economy could be effected by abandoning them. The elaborate "professional service" sheets in connection with the balloting for members have been serviceable, but expensive. They could be discontinued if economy is desired.

IV.

The volume of *Transactions*, however, and the membership list as a professional directory, do not constitute the only return which members receive for their dues. While a part of the return is capable of being expressed in figures, there is an imponderable value which attaches to membership in a professional organization of national character which has a creditable and distinguished standing in the community. As a result of the methods which have prevailed with respect to the election of members, it has come to be the case that membership in the American Society of Mechanical Engineers has a meaning as a professional indorsement; if the man was not a desirable and capable practitioner of engineering he would not have been able to pass the ordeal of election. Furthermore, the Society at its conventions secures privileges in the way of excursions, visits to engineering establishments, and social opportunities, which are open to members, and which would not be within the reach of those who are not connected with the Society. Those who have availed themselves of the privilege, furthermore, have discovered that the officers of the Society can render, both officially and otherwise, services to the members in the matter of introductions to sister societies; and for the younger members, and even for others, there is a continual interchange, through the Society channels, in bringing eligible engineers in touch with positions vacant in their chosen line.

It has a value to every member that the Society to which he belongs has a headquarters at some certain point, which can be used by him as a home or for business purposes. It is apparent, therefore, that for the conduct of its official business the Society must be officered, and must have an adequate staff for its accounting and other clerical business, of which, however, a very considerable proportion may properly be charged against the volume of *Transactions*, as an indirect charge contributing to the expense of that volume to the individual member.

Taking the expenditure of the Society for the same four years as are covered by the preceding table, and subtracting such expenditure as is not universal in its application to every member, and dividing that total by the number of members in the Society for that year, the totals attaching to each year covered by the corresponding volume appear in the table below, and opposite each is placed the average amount collected from each member of the Society:

Years.	Volume.	Cost.	Average Collected Per Member.
1896–1897	18	$14.64	$12.79
1897–1898	19	16.37	12.60
1898–1899	20	16.00	13.05
1899–1900	21	18.50	13.02

The expenses omitted have been those connected with the purchase and maintenance of the library of the Society, repairs, and internal expenses connected with the headquarters of the Society, outside of the mere office or accounting room. It appears that for the last three years the Society has not been able to meet its total expenditure from *dues only*. It has only kept its head above water by other sources of income, such as sale of its publications to outsiders and by applying a portion of the initiation fees each year to current expenses. It is regarded as unsound financial policy to spend the initiation fees in this way; but the members have been receiving from the Society so much under the present system that it has been impossible to conduct it as it has been conducted without drawing on this fund.

As is shown by the above table, either the expenditure of the Society must be curtailed in directions which would be followed by a corresponding loss of efficiency and of the return to each member, or the dues paid by each member must be raised to provide a fund from which present indebtedness may be paid, any unusual demand may be met, or any unusual opportunity be availed of.

V.

With an increased return from the members in the matter of dues the usefulness of the Society and its return to its members would be capable of being increased. It is aside from the present purpose to make statements which might appear to be binding as a policy upon future years; but it will be at once apparent that if the Council were in a position to expend larger sums each year there would be certain very desirable purposes for which such expenditure might be made. One of these would be the conduct of investigations along professional lines by committees of experts. The foreign societies of engineers have laid stress upon this detail; and their dues, which are larger than those of the American society, have made this step possible. A second line of usefulness would be the preparation and distribution of technical index material, culled from sister societies in this and other countries and from technical literature of all sorts. A system of circulation among the members, whereby its library could be made available to those who might not happen to be resident in the neighborhood of the city where it is located, could be inaugurated if money was at hand to be expended for this purpose. The extent and value of the library itself could be increased. There are many other directions in which money could be expended with profit were it at hand, and which would occur to various members.

VI.

It has been increasingly obvious to all who have been present at recent conventions of the Society in New York City, and to those who have examined the limitations surrounding the Society library, that some provision for more satisfactory housing of the Society and its library would have to be considered before long. The present house has been occupied by the Society for eleven years, and has been conducted with economy and a minimum staff. Certain criticisms have rightly attached to the management of the Society incident to the economy which has been forced upon it by the conditions of this policy. Whether or not it shall prove desirable in the near future to alter and enlarge our present building or build a new and more suitable one, or to enter into a species of federation with one or more sister societies, or to form some satisfactory scheme of joint occupancy which shall not introduce the difficulties of joint ownership, the fact

remains that to make *any* change from the present scale of expenditure to that larger scale which the growth and importance of the Society demands, must make it necessary that an increase in resources should be secured. If the pride of the Society membership in its efficiency, and their interest in stimulating its growth are as great as the Council believes them to be, the shortest road to attain the desired result would be secured by such coöperation from the entire membership as will result in increasing the dues.

VII.

The proposed amendment raises the annual dues of the active or voting membership, in both the member and associate grades, from $15 to $25, and the dues of juniors from $10 to $15. It would, of course, be possible to increase the dues of members and associates only sufficiently to meet all demands. It should not be overlooked, however, that in most respects the junior member profits by his membership to the same extent as the other grades, and that if the proportionate number of junior members is increased the expense limit will be reached again, and at an early date. The junior members include those who are acquiring their professional experience, and in many ways the value of the Society to them is very great. They constitute, furthermore, an element of strength to the Society by the gradual procedure of promotion to take the place of the older men. The dues of the Institution of Civil Engineers of Great Britain, whose position in that country is the closest parallel to that occupied by the American Society of Mechanical Engineers in America, are four guineas a year. The Council has felt that it is decidedly a better policy to raise the dues to such a point as seemed to be indicated by the experiences and wisdom of the English Society rather than to adopt a policy of "tinkering" with the constitution and he rate of dues at frequent intervals. It seems better to raise the dues to the point at which they will be likely to remain.

It is the opinion of some members that while the increase in the annual rate of dues may perhaps cause a limited number of resignations, the increased value of membership in the Society will result in drawing to the Society an increasing number of engineers of desirable character, which will more than offset the small loss from withdrawals of those less vitally interested in engineering. When the dues were increased in 1891, the loss of membership attributable to that increase was practically inappreciable. At $25 a year, the increase for the members would be less than three cents a day; and at $15 for the juniors, less than two cents. It is felt that to practising engineers of the type represented in the Society membership this increase is practically nothing, so far as its restricting or prohibitory effect is concerned.

The Council, having given most careful consideration to the questions which are involved in this general subject, and believing that the course suggested by the amendment is the best for the interests of the Society—in which view the ex-presidents have agreed—desires to secure the benefit of your judgment, so that it may have due weight at the meeting. A second issue of this circular, nearer the date of the annual meeting, will be made, which will include a reply blank, on which expressions of your individual opinion can be formulated, which will serve to guide the Council, in the first place, as to its action towards the problem, and possibly serve as an indication to the voting membership at the annual meeting itself on which side of the question the majority lies. It will be apparent that the broad question is that of increasing the dues, on the one side,

or of curtailing the expenditure of the Society and reducing the benefits to its membership, upon the other.

F. R. HUTTON,
Secretary.

It was later decided at another very large meeting of the Council, at which this question was further discussed, that in view of the fact that a letter-ballot was not provided specifically by the Rules as a means of ascertaining the opinion of the membership in the matter of an amendment, that to order such a ballot would be illegal, and that the expression of the entire membership upon the question of increasing the dues should be secured by another method. To this end the Council, after taking legal advice, directed the issue of a circular, accompanied by a form of proxy, which should be sent to the entire voting membership, requesting them to express themselves upon the subject by returning the proxy with instructions as to the way that they would like to have it used by the person whom they should designate. The circular and proxy were issued in the following form :

PROPOSED INCREASE IN DUES AND PROXIES.

DEAR SIR : At the meeting of the Society in Milwaukee, May, 1901, under the provisions of Article 45 of the Rules concerning amendments, notice was given of the following proposed change in the provisions of Article 18 :

"WHEREAS, a resolution has been presented in the Council by one of its members, looking to the advisability of an increase in the rate of the annual dues in the Society, and whereas the Council has given favorable consideration to this proposition,

"Notice is hereby given of an amendment to be taken up and considered at the annual meeting in December, 1901, to amend Article 18, as follows :

"The initiation fee of a member or associate shall be $25, and the annual dues shall be $25, payable in advance. The initiation fee of a junior shall be $15, and his annual dues $15, payable in advance. A junior being promoted to any other grade of membership shall pay an additional initiation fee of $10. Any member or associate may become a life member, in the same grade, by the payment of $350 at one time, and shall not be liable thereafter to annual dues."

The Secretary of the Society, by direction of the Council, issued a circular letter, bearing date of September 21, 1901, in which a presentation was made of the reasons for the proposed amendment. It is only right to say that this question had been considered by the Council a year before it was offered to the membership, and was very carefully gone over at a meeting held in Milwaukee. On October 31, 1901, another large meeting of the Council was held, which gave long and full consideration to the subject, and it was directed that the issue of a circular in the name of the undersigned members of the Council, who were present at the meeting, should inform the membership of the results of their deliberation.

The Council passed *unanimously* the following resolution :

"*Resolved*, That it is the opinion of the Council that the proposed amendments to the Rules in the form in which they were presented at the Milwaukee meeting meet with their hearty approval, and it is their hope that these amendments may be passed in that form at the next annual meeting."

It was, furthermore, the opinion of the Council at its meeting that an amendment of the character in question should be acted on by the entire membership if it desired to do so. The Rules of the Society do not provide for a letter-ballot on an amendment to its Rules; but the general laws concerning incorporated organizations make provision for proxy voting of the membership at their general annual meeting. In view, therefore, of the illegal and unconstitutional character of the letter-ballot, the Council, upon legal advice, have directed that proxy blanks should be sent to the entire voting membership, with the request that these should be signed in the presence of one witness, and forwarded for presentation at the annual meeting, when the question of the amendments is up for consideration. The undersigned members of the Council will be glad to act as proxies for any member who will give instruction as to the form in which he desires to have his vote cast. Stamped envelope accompanies this circular. The proxies should be delivered to the persons to whom they are addressed so as to be in New York City before 10 A. M. on Wednesday, December 4, 1901.

The Council desires to bring definitely before the voting membership the issue to be met. In brief, it is as follows:

I. The present return to members, in the form of publications and otherwise, costs a sum per annum greater than the aggregate sum received from the members in dues. To maintain the present return at the present rate of dues is to run the Society in debt. It is in debt now to its printer.

II. The present expenditure can be curtailed and the dues kept at their present figure; but this will mean the abolishment of some of the advantages which the members now enjoy. This will be done, if the majority of the members prefer to have it so, rather than to raise the dues.

III. It is the decided opinion of the Council, however, that the best interests of the Society will not be served by a policy of retrenchment. The wiser course, in its opinion, would be the opposite policy, or that of advancement. The Society should increase the number and value of its publications; it should develop its professional library; but even more important than this, the Council believes, the profession of mechanical engineering, and its own interests, and those of its members, would be best served by putting the Society in such position that it would have money in its treasury for the conduct of research and investigation, under committees of competent members, who should furnish the brains and direction for such researches, while paid assistants and the necessary apparatus could be provided from the Society's income. The reports of such researches in the *Transactions* would enhance their value, and the Society would take its position as the leading exponent of the highest grade of professional achievement. Will the membership sanction this policy by raising the dues for this object? Does the membership at large agree with the Council that this broader policy is the wise and permanent one? The vote is really on this question.

It goes without saying, that the good judgment of the Council will be pledged to protect the Society from extravagance in management and in method, whether the dues are increased or not.

It may be desirable to say further that the question of the increase in the dues is practically independent, for the present at any rate, of any question affecting the headquarters of the Society and the accommodation of its library.

The undersigned would add, furthermore, that if the proposition to increase the dues for the purpose of broadening the scope and usefulness of the Society is not favorably entertained by a considerable majority, it will be their opinion that the time is not ripe for the passage of such amendments as are proposed. It is therefore desirable that the Council should be informed just as definitely concerning favorable opinion and sentiment with regard to the amendment, as that it should be advised of adverse preferences. *Every member, for this reason, is earnestly urged to make use of the proxy and state his opinion, by letter or otherwise, to the individual whom he selects.* The vote at the meeting will be taken by ballot in order that it may be properly scrutinized by tellers.

Respectfully,

E. D. LEAVITT,	Past President,	1882–1883.
HENRY R. TOWNE,	" "	1888–1889.
OBERLIN SMITH,	" "	1889–1890.
ROBERT W. HUNT,	" "	1890–1891.
CHAS. H. LORING,	" "	1891–1892.
CHAS. E. BILLINGS,	" "	1895.
JOHN FRITZ,	" "	1895–1896.
CHAS. WALLACE HUNT,	" "	1897–1898.
CHAS. H. MORGAN,	" "	1899–1900.
S. T. WELLMAN,	President,	1900–1901.
DAVID TOWNSEND, JAMES M. DODGE, JESSE M. SMITH, AMBROSE SWASEY,	Vice-Presidents,	1900–1902.
R. H. SOULE, FRANCIS H. BOYER, A. H. RAYNAL, D. S. JACOBUS,	Managers,	1900–1903.

Know all men by these presents, That I,.................................,
of..............................., the State of..........................,
do hereby constitute and appoint..
or any one of the said persons named, my lawful attorney and agent, for me, and in my name, place, and stead, to vote as my proxy at the annual meeting of the members of the American Society of Mechanical Engineers, to be held on the fourth day of December, A.D. 1901, and at any adjournment of said meeting, upon the following proposed amendments to the Rules of the Society :

WHEREAS, A resolution has been presented in the Council by one of its members, looking to the advisability of an increase in the rate of the annual dues in the Society, and whereas the Council has given favorable consideration to this proposition,

Notice is hereby given of an amendment to be taken up and considered at the annual meeting in December, 1901, to amend Article 18, as follows:

"The initiation fee of a member or associate shall be $25, and the annual dues shall be $25, payable in advance. The initiation fee of a junior shall be $15, and his annual dues $15, payable in advance. A junior being promoted to any other grade of membership shall pay an additional initiation fee of $10. Any member or associate may become a life member, in the same grade, by the payment of $350 at one time, and shall not be liable thereafter to annual dues."

Or upon any substitute or amendment that may be offered thereto, and upon all questions, motions, resolutions, and matters as shall come before the meeting,

pertaining thereto, as fully and with the same effect as I might or could do were I personally present, hereby ratifying and approving anything that my said attorney and agent may do in the premises ; and I hereby revoke any powers of attorneys or proxies heretofore given by me to any person or persons whomsoever.

In witness whereof, I have hereunto set my hand and seal this............day of................., A.D., 1901.

....

Signed, sealed, and delivered in the presence of (one witness)

....

The Council directed, furthermore, that in view of the important character of the question, the vote of the Society at the annual meeting, on the adoption of the proposed amendments, should be by ballot.

The Council has received and considered a most elaborate and detailed report from a committee of the members of the Society resident in eastern Massachusetts, urging that the Council should select the city of Boston as the place for the spring meeting of 1902. The reasons which were advanced have appeared to the Council to be so cogent, that it has resolved to hold the spring meeting of 1902 in the city of Boston, pursuant to the courtesy of the full arrangements for such a meeting which have been inaugurated by the interested members.

The Council has received from President Mansergh, of the Institution of Civil Engineers of Great Britain, a cablegram upon the death of President McKinley. By direction of the Council, this cablegram and the answer of the secretary to the message of sympathy have been spread in full upon the minutes of the Council, and are in the following terms :

CABLEGRAM.

"Mansergh, President, expresses the profound sorrow and sincere sympathy of the Institution of Civil Engineers on the tragic death of your honored chief, McKinley."

REPLY.

"To the President of the Institution of Civil Engineers.

"The American Society of Mechanical Engineers expresses with profound appreciation its recognition of the courtesy of President Mansergh of the Institution, in sending a cablegram of sympathy in connection with the lamented death of President McKinley.

"The feelings of all thoughtful Americans at this juncture have been so profoundly stirred that the thought of the whole nation stands aghast. The transatlantic sympathy, both personal and official, has been exceedingly grateful.

"Very truly,

"F. R. Hutton,

"Secretary."

The Society was invited officially by the president of the New York University to appoint its president and secretary as officials to take part in the unveiling ceremonies of the tablet in the Hall of Fame of New York University, in memory of Eli Whitney, inventor of the cotton-gin. The date for the ceremonies fell coincident with the Milwaukee meeting, so that the duty of representing the Society was assigned by the Council to past-Presidents R. H. Thurston and Henry R. Towne. A brief address was made by Professor Thurston as the share of the Society in the ceremonies.

A committee of three, consisting of Messrs. Towne, R. W. Hunt, and John Fritz, has been appointed to consider a proposition made in the public press of New York City, that the monument to Mr. Alex. L. Holley, one of the founders of this Society, which is now standing in Washington Park, in New York, had become inappropriately placed by reason of the changes in that neighborhood. The recommendation looking to its removal has been under consideration, but no definite action has been reported at this time.

The Society's committee entrusted with procuring funds, and obtaining the permission of Trinity Church Corporation for the erection of a memorial to Robert Fulton in the Trinity churchyard, New York, has consummated its labors, and the formal services connected with the dedication of this memorial form part of the occurrences of the annual meeting of 1901. The Council have executed an agreement with the Trinity Corporation concerning this memorial.

It has been decided by the Council that it could not this year assume the expenses of a delegate to represent the Society at the International Conference at Budapest, Hungary, in September. No action was therefore taken in this matter.

The Council has also considered the usual number of routine applications for gifts of its *Transactions* to public or endowed libraries, and has uniformly adhered to its decision that the best arrangement for such requests would be the granting of the usual rate which is permitted to members of the Society buying the sets of its *Transactions* previous to their election.

The Council has directed that there should be appointed an Executive Committee of its own number, to consist of the President and Secretary and three other members, in each year, to whom might be referred questions to be considered and acted upon between the stated meetings of the larger body. The

Executive Committee for the current year has been Messrs. Wellman, Hutton, Warner, Taylor, and Waite.

The Council would report for record the deaths of the following members during the Society year:

Louis I. Seymour, June 14, 1900; Mellen S. Harlow, December 29th; Alex Henderson, January 12, 1901; Wm. McMannis, January 19th; E. C. Darley, February 16th; Geo. H. Starbuck, March 7th; Saml. W. Skinner, May 20th; Jos. Hirsch, Honorary Member, June 22d; A. B. Tower, July 8th; Jas. F. Lewis, July 23d; E. G. Parkhurst, July 31st; Stephen Greene, Nov. 7th.

The present membership in the Society in its various grades, at the time of this report, is as follows:

Honorary Members	18
Members	1,615
Associates	159
Junior Members	537
Total	2,329
Life Members	96

The Council would also present the report of its tellers, appointed to count the ballots cast for members seeking to connect themselves with the Society just previous to the annual meeting. The report is as follows:

REPORT OF TELLERS OF ELECTION.

The undersigned were appointed a committee of the Council to act as tellers, under Article 11 of the Rules, to scrutinize and count the ballots cast for and against the candidates proposed for membership in their several grades in the American Society of Mechanical Engineers, and seeking election before the XLIVth meeting, New York, 1901.

They have met upon the designated day in the office of the Society, and have proceeded to the discharge of their duty. They would certify, for formal insertion in the records of the Society, to the election of the following persons, whose names appear on the appended list, in their several grades.

There were 589 blue ballots cast, of which 7 were thrown out because of informalities. The tellers have considered a ballot as informal which was not endorsed, or where the endorsement was made by a facsimile or other stamp.

A. M. Waitt,
Stevenson Taylor,
R. H. Soule,
Jesse M. Smith,
Tellers of Election.

As Members.

Abbott, Arthur V.
Abercrombie, Jas. H.
Abrams, Herbert T.
Adamson, Daniel
Aldrich, Jno. G.
Bertsch, Jno. C.
Blake, Clinton F.
Burwell, Robt. T.
Capp, Jno. A.
Cattell, Wm. A.
Coburn, Howard L.
De Leeuw, Adolph L.
DeWolf, Jno. O.
Dillon, Benj. H.
Forsyth, Robt.
Fullenwider, Henry L.
Gabriel, Chas. R.
Gerrish, Wm. H.
Hammarberg, Arndt. L.
Harned, Albert W.
Harris, Jno. J.
Henry, Geo. J., Jr.
Honsberg, August A.
Hoopes, Morris
Howell, Frank B.
Jackson, Lucian C.
Jackson, Wm. B.
Jones, Edw. C.
Kennedy, Thos. J.
King, Geo. I.
Krummel, L. C.
Lardner, Henry A.
Lea, Edward S.
Lazenby, Francis A.
Lofts, David
Machold, Chas. E.
Malochée, Henry J.
Morgan, Jno. R.
Mullaney, Jno. J.
Murray, J. Weidman,
Naegeley, J. C.
Nickerson, A. T., Jr.
Parsons, Wm M.
Pitchford, Jno. D.
Reunert, Theo.
Tagge, Arthur C.
Viola, Bartholomew.
Whitlock, Eliott H.
Wieland, Chas. F.

As Associates.

Bolles, Frank G.
Brown, Chas. F.
Crane, Edw. S.
Croll, Andrew G.
Higdon, Jno. C.
McLeod, Daniel T.
Pollak, Chas. P.
Ryder, Malcolm P.
Terwilliger, Harry L.
Voss, Otto C.

Promotion to Full Membership.

Alexander, H.
Brandon, Geo. R.
Johnson, Jos. E., Jr.
Katte, Edwin B.
Middleton, Percy H.
Monroe, Wm. S.
Steele, Walter D.
Wallace, Jos. H.

Promotion to Associate.

Vanderbilt, Cornelius.

As Junior Members.

Allen, Chas. M.
Angus, Robt. W.
Avery, Jno. S.
Bailey, Fred'k W.
Barkley, Matthew B.
Batten, Percy H.
Bernhard, Richard
Blake, Francis E.
Brooks, Louis C.
Buvinger, Geo. A.
Casler, Herman
Collier, Wm. H.
Cunningham, C. Wayne
Curtis, Edma H. Jr.
Gladden, Chas. S.
Gray, Jno. L.
Hagy, Jas. L.
Hogle, Milton W.
Holcomb, Alpheus E.
Hollander, Emanuel
Hopkins, Geo. G., Jr.
Idell, Percy C.
Jennings, Edwin M.
Lunger, Walter G.
McClintock, Edw.
Meissner, Chas. F.
Nolde, Fred'k.
O'Neil, Fred'k W.
Phillips, E. L.
Riedel, Arthur E.
Rutherford, Gordon S.
Sears, Richard H.
Smith, Ernest L.
Starbuck, Geo. F.
Van Valkenburgh, R. D.
Veitch, Thos.
Young, Wm. A.

At the close of the report of the Council, the second order of business was the report of the Finance Committee, as follows:

ANNUAL REPORT OF THE FINANCE COMMITTEE OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, 1900–1901.

For the fiscal year 1900–1901 the Finance Committee of the American Society of Mechanical Engineers would respectfully report to the Council and the Society the following statements of receipts and expenditures which have passed under its direction on behalf of the Society during the year beginning November 12, 1900, and ending November 13, 1901.

Secretary's Balance Sheet for the fiscal year, ending November 13, 1901:

Dr.		Cr.	
To receipts for the year 1900–01, all sources (itemized below)	$42,558 18	By Cash to Treasurer	$42,558 18

Itemized statement of receipts and expenditures of the Society for the fiscal year 1900–1901:

Receipts. Dr.		*Disbursements.* Cr.	
Initiation Fees	$4,910 50	Publications	$6,980 85
Current Dues. $27,606 82; Past Dues.... 1,224 91; Advance Dues. 324 46	29,156 19	Mail and Express	2,926 43
		Salaries	9,738 06
		Office Expenses	398 92
Sales of Publications	2,720 45	Engraving	819 92
Binding Transactions	138 25	Contingent	28 50
Engraving	155 45	Binding *Transactions*	1,913 50
Life Memberships	1,200 00	Meetings	2,846 39
Office Expenses (Misc.)	15 05	Committee Work	69 11
Mail and Express (Misc.)	3 44	Badges and Certificates	614 01
Hall Rentals	825 00	Travelling	300 00
Room "	1,227 58	Insurance and Safe Deposit	17 00
Badges and Certificates	991 50	Rent, Interest, and Taxes	3,175 21
Lighting (use of lantern current)	5 00	Printing Circulars, Catalogues, Office Forms, etc.	2,530 78
Check Collection Charges	70	Stationery Supplies	292 47
Meetings, Subscriptions, etc.	782 72	House Supplies and Furniture	317 66
Travelling (refund)	75		
Sales Duplicate Books from Library	425 00	Library (book purchase and binding)	205 10
Employers' Bulletin (paid us for small expenses)	60	Janitorial Supplies	126 53
		Fuel	284 75
		Lighting (gas and current)	873 34
		Laundry	402 30
		Repairs, House, Furniture, etc.	1,610 96
		Col. Out-town Checks	21 88
Total Receipts	$42,558 18	Total Regular Expenses	$36,493 67

Brought forward	$42,558 18	Brought forward	$36,493 67
Cash in Treasurer's hands first of year 1900-1901	248 07	*Unusual Expenses.*	
		New Heating and Ventilating Plant ... $4,486 00	
		European Expenses and Engrossed Resolutions sent Foreign Societies 687 29	
		Dues, Overpayment Refunded Member ... 15 00	
		Total Unusual Expenses	5,188 29
		Total Disbursements, year 1900-1901	41,681 96
Total	$42,806 25	Cash on hand, end of year 1900-1901	1,124 29
Cash in Treasurer's hands first of year 1901-1902	$1,124 29	Total	$42,806 25

At the time of this report there remains outstanding uncollected accounts due the Society to the end of the year 1900-1901, as follows:

From Members, Dues, etc.

3	men owe for initiation fee	$55 00	
57	" " " dues for the year 1900-01, just closed, at $15.	855 00	
19	" " " ditto, at $10	190 00	
54	" " " dues of 1900-01 and previous years from two to four years back	1,964 24	
2	" " " dues over four years	165 00	
9	" " " small balances for papers, badges, etc.	26 32	
	Total, 144 men (about 5¼% of the entire membership)		$3,255 56

From Miscellaneous Accounts.

2	societies for hall rent	$50 00	
21	persons for room rent	168 69	
12	non-members for publications	213 00	
	Total from 35 persons		$431 69
	Total amount outstanding and uncollected		$3,687 25

Due to the action which has been taken by the Council under Article 19 of the Rules, on men who owed a number of years' back dues and from whom the Society seemed to be able to get no satisfactory and definite responses to statements and letters sent them, the sum shown above as due the Society at the end

of the fiscal year 1900-1901, *i.e.*, $3,687.25, is practically all collectable, and the larger portion of it will without doubt be collected during the coming year.

ASSETS AND LIABILITIES.

End of Fiscal Year 1900-1901.

Assets.

Interest in property at 12 West Thirty-first Street, New York	$29,000 00	
Stock of bound and paper-covered copies of the *Transactions* of the Society, Vols. I. to XXI	15,900 00	
Badges in stock for sale	126 00	
Outstanding indebtedness from members as itemized in statement above	3,687 25	
Cash on hand in bank, as per report above	1,124 29	
		$49,837 54

Liabilities.

Notes payable	$10,673 00	
Rent due to Mechanical Engineers' Library Asso.	2,625 00	
Sundry minor accounts	650 00	
		$13,948 00
Excess of assets over liabilities		$35,889 54

The above statement does not include such property as pamphlet copies of the papers which are available for sale, nor does it include the office furniture of the Society—safe, typewriters, etc.—in use, which have been considered as having no estimable cash value. It does not, furthermore, include a valuation for the sterotyped plates of the volume, but only such assets as are convertible under favorable conditions into cash.

The valuation for the copies of the *Transactions* has been made on the basis of estimates for their reproduction in editions of two hundred and fifty, from stereotyped plates where the volumes have been thus stereotyped, and on the price for reproduction of Volumes IV. to XI. in editions of the same size for which no plates are in existence. The selling price of this stock if it can be entirely disposed of would be in excess of $24,000.

With respect to the liabilities, it may be explained that the amount under "notes payable" covers a payment made to the Society's printer in the form of three notes falling due after the receipts for the current fiscal year shall have become due and payable.

There has always been an open running account with the printer at the end of each Society year, but this account has grown to twice the usual proportion by reason of the payment of the bill for installing the heating and ventilating apparatus, from current income, which has made it impossible to meet the bills for the printer by cash payments as they were presented during the year. The Society has also refrained from paying the friendly Mechanical Engineers' Library Association the amount due for rent under the lease. This statement will also make it apparent why the amount credited to publications in the cash statement is smaller this year than usual, and less than the normal amount which should be expended for this purpose in any year.

In figuring upon the total accumulations of the Society during a period of years, the assets of the Mechanical Engineers' Library Association form a part of the directions in which such accumulations have been set aside.

MECHANICAL ENGINEERS' LIBRARY ASSOCIATION.

COPY OF ANNUAL REPORT OF THE TRUSTEES OF THE MECHANICAL ENGINEERS' LIBRARY ASSOCIATION FOR 1900–1901.

The summary of receipts and disbursements of the Trustees from November 15, 1900, to November 13, 1901, is appended.

Secretary's Balance Sheet for year 1900-1901:

Dr.		Cr.	
To balance on hand first of year 1900-1901	$33 28	By Expenditures as itemized below	$3,085 05
To receipts as itemized below.	3,487 00	By Cash on hand end of year.	435 23
	$3,520 28		$3,520 28

Itemized statement of Receipts and Expenditures for fiscal year 1900–1901:

Receipts. Dr.		*Disbursements.* Cr.	
Receipts, Fellowship Fund	$136 00	Interest on Mortgage	$1,402 50
" Sinking Fund	346 00	Salaries	840 00
" Office Rent	3,000 00	Library and Book Purchase	25 00
" Refund Salary	5 00	" Work in connection with new Catalogue of same	196 05
	$3,487 00	General Printing	6 50
		Bonds, two notes of $300 each given last year to two holders of three bonds each of M. E. L. A.	600 00
Cash on hand first of year	33 28	Interest paid on above notes	15 00
		Total Expenditures	$3,085 05
		Cash on hand end of year 1900-1901	435 23
	$3,520 28		$3,520 28
Cash on hand first of year 1901-1902	435 23		

At the time of this report there is due the Association the sum of $2,656.00, as follows:

Five Subscriptions to Funds	$31 00
American Society Mechanical Engineers, for Rent	2,625 00
Total	$2,656 00

All bills against the Association are paid to this date.

ASSETS AND LIABILITIES.

Assets.

Cash on hand as above	$435 23	
House and Lot, 12 West 31st Street, New York	80,000 00	
Furniture and Equipment	5,000 00	
Books and Manuscripts	11,000 00	
Subscriptions due by five men	31 00	
Rent due by American Society Mechanical Engineers	2,625 00	
Total Assets		$99,091 23

Liabilities.

First Mortgage held by New York Academy of Medicine	$33,000 00	
Equity in property at 12 West 31st Street, New York, held by the American Society Mechanical Engineers	29,000 00	
Total Liabilities		62,000 00
Excess Assets over Liabilities		$37,091 23

The special order of business appointed for the morning session was the consideration of amendments to the Rules, of which notice had been given, in concurrence with the requirements of the constitution, at the Milwaukee convention. The discussion on this subject was opened by ex-President Robert W. Hunt, who read the resolution to amend, as follows:

Mr. Robert W. Hunt.—I move that Article 18 of our Rules be amended to read:

> The initiation fee of a member or associate shall be $25, and the annual dues shall be $25, payable in advance. The initiation fee of a junior shall be $15, and his annual dues $15, payable in advance. A Junior being admitted to any other grade of membership shall pay an additional fee of $10. Any member or associate may become a Life Member in the same grade by the payment of $350 at one time, and shall not be liable thereafter to annual dues.

In making this motion, which I do at the request of the Council, I want to assure you that it is done after very careful consideration, and with an earnest desire to serve the best interests of the organization. For this reason I know that I am echoing the voice of every member of the Society when I express my belief that, no matter how the question shall be decided, whether for the amendment or against it, that the decision will be reached and each individual will vote with the same earnest desire to promote the welfare of the Society that I assure you I have in making the motion. I want, further, to assure the voting membership that I myself as a past President,

and all the other members of the Council, pledge you that we will carry out to the best of our ability your wishes in this matter as they shall be expressed. If you decide in favor of the increase of the dues, we pledge you that the increased revenues will be used judiciously and will not be wasted or extravagantly expended because the Society has more funds. If, on the contrary, you decide that economy must be practised to the extent of cutting off certain desirable returns to the membership, and curtailing the Society's operations in various directions so as to make the present income tally with the expenditures, I pledge you, on the part of the Council, that your wishes shall be obeyed to the utmost. I assure you that there is no feeling or sentiment in this matter, except that one which expresses itself in love for the Society. We are facing a condition of affairs which has not perhaps been made as clearly manifest to the membership of the Society as it would have been if the Society were not an open organization. The reason it has not appeared in the past as clearly as we are making it appear now is because your initiation fees have gone into the general fund for expenditure, and the running account which the Society carries with the firm which prints its *Transactions* is an account which is never closed with the close of the Society's annual account, and the gradual increase of the amounts outstanding and due for the printing of the Society *Transactions* has been increasing year by year until this year it has grown to a proportion to which the attention of the Council has had to be directed. This state of affairs if allowed to run on indefinitely, with a gradual accumulation of indebtedness, can have but one end.

How can we face this proposition? The Council have already canvassed your expenditures, and have taken action to reduce them in directions where the return to the members from their dues would be the least affected. But when all this is done, the Society will not have paid its debt, nor will it have brought its running expenses very much below the income from dues. It is the opinion of the Council that the initiation fees should not be expended as current income, since that policy persists on the assumption that the Society will grow at the present phenomenal rate for indefinite years. The Council have not felt inclined to make radical changes in their policy until the desire of the members for such change has been very clearly expressed. The Council wishes to have the Society in the posi-

tion of feeling itself one of the greatest and most progressive organizations of its kind in the world, and not to transform it into an organization upon a lower plane, economizing in every way, giving less service to its membership, stopping the publication of certain desirable issues, and scrutinizing every benefit until the Society is not only out of debt, but in a position to move forward. I submit that, in my opinion, the policy of violent retrenchment is not a good one. It does not seem to me that this is the time for the Society to think that they have to do such a thing. On the contrary, we should assess ourselves—which is what this increase of dues will mean—for a year or two, so as to pay what we owe at once; then, with the greater income and a close scrutiny of every purpose for which our income is expended, the ultimate result would be that every dollar would yield us even greater returns than at present for the membership which we carry in the Society.

The question has been raised, "Can the members individually afford to meet an increase of dues?"

I would like to call your attention to the fact that no man can become a full member of this Society until he has passed the limit of thirty years of age. Is it to be supposed that a man with mechanical or engineering ability in any line, and who has reached thirty years of age, cannot afford to spend $25 a year to belong to a Society which gives him more technical information in his profession than any other Society in this country or abroad, and with the pledge that with this increase, and with the belief that with such increase, the work of the Society would be extended so that what he receives would be greater than its due? I personally do not believe the $25 dues will prove a hardship. At the same time, it is apparent that this question must be determined by every man for himself.

A direction of economy which has been suggested by some members is to discontinue the issue in advance of the meeting of the papers which are to be read. We are told that everyone gets these in his bound volume of *Transactions*. In reply I ask, "When does this come to him?" It comes at the end of the year, after a year's work in his profession, so that these papers are ancient history, of comparatively little value except for reference. In rejoinder, we are referred to the summaries of our papers in the weekly or monthly issues of the technical journals. The difficulty here is, that, while it is true they are

summarized, yet the blue pencil of the editor has often cut into the very vitals of the papers, so that their important mission to us has been eliminated. A man in the editor's chair tells you what you ought to read and what his paper chooses to publish, and if by mischance he does not get it in advance of a friendly rival he does not insert it at all.

It seems to me that an artisan cannot do good work without tools. It is no use to give a man a broad-axe, a steel square, and a jack plane, and tell him to build a palace car. It is no use to give an engineer an old arithmetic, a foot rule, and a piece of chalk, and ask him to design a complicated piece of machinery. The competition is too great, and we must be up with the times. We must know what others are thinking about and are ready to do, and it ought not, in my opinion, to be a year after they have completed their work.

The increase of dues, furthermore, will give the Society an added opportunity. If its income shall be thus increased, it will allow the Society in an organized way to pursue a course of investigation in technical matters which will be of the greatest interest and benefit to the whole profession. I would refer you to the work of our present committees, made up of earnest and able men, and ask you to notice how long they have been at work upon the duties committed to them. They are perfectly willing to give the work of their brains, but cannot afford to give time for the necessary drudgery of such committee work, and particularly for the work of investigation, which can be made so important a field for the activities of such committees. If, on the other hand, the Society had a fund which, judiciously administered, could employ competent persons for the manual part of the committee's work, there are members in the Society who would give the time necessary for the brain work; and I can scarcely convey an adequate idea of the value to the profession which would follow, and the standing of the Society would be put even higher than we rejoice to see it to-day.

I most earnestly hope that the motion will prevail.

Mr. Francis H. Boyer.—I rise to second the motion to increase the dues, and, after what has been so ably said by the speaker who has preceded me, it would seem that a little explanation might be acceptable as to the origination of the resolution, and perhaps, also, the opposition to it. The necessity for the increase in the dues, as it has appeared to the Council, is told in

the report of the Auditing Committee. The condition of affairs has not been unknown to the Council for some time, and at the Milwaukee meeting notice was given that this question would come up, so that we might get together and talk it over among ourselves. It was not intended that the matter should become a newspaper topic for discussion in the press and for publication broadcast before the cause had been stated and made known to those interested. I will venture the statement that three-fourths of the members of the Society outside of the Council did not know the character of the necessity for having money to meet our indebtedness. I have a secret to tell you about a meeting of the Council held on the 31st of October last. Sitting around the table were eighteen men; we went into session at three o'clock in the afternoon; at six o'clock we adjourned for dinner, and at that time the question of the treatment of this resolution had not been reached. It was on the docket, but there seemed to be a reluctance to take it up. After dinner the question was taken up, and it will interest you to be told that the first three speeches which were made were emphatically in opposition to the resolution, and those of us who were looking on felt that a majority of the members present were opposed. Finally, however, past-President Hunt, of Chicago, took the floor, and, in his easy, quiet way, he told us what, in his opinion, would be the consequences of keeping on in the present way. The members of the Auditing Committee, of course, were well informed, but the average member of the Council had not given it the attention at that time which those had exercised who had been brought in contact with these affairs.

It took ten minutes for past President Hunt to tell the story, and it took about a quarter of a minute, when he was through, for every man to come out in favor of the resolution and to take the unanimous action which has been reported to you.

We appreciated at that meeting that a serious injury had been done to the movement to increase the dues by the publication of partial information concerning the resolution and of the disasters which would follow favorable action upon it. It seemed to us that, without adequate knowledge concerning the necessity for the proposed action, the reading public had been favored with criticisms broadcast, and applications for proxies to be used against the movement. The question is like a family matter, and without money to pay our bills, the Society, like a

family, cannot exist. We cannot hold our heads up honorably otherwise, and yet proxies to prevent increase in income to pay these bills were invited, to be held over the heads of the Council by those who did not know the reason for the action to be taken. I wonder if the Chinese law is known to you. If a man in China is charged with a crime, he must prove his innocence. But the case here is, that, without knowing what the crime was, and without knowing the evidence, adverse action is held over the heads of the Council. This is the reason why the circular was issued which asked every member, on the basis of a fuller knowledge of the facts, to present his opinion. Some of the letters which have accompanied these proxies would be amusing reading. Some of them said that our *Transactions* are of no value whatever; while, on the other hand, one of the most prominent members of the Society has said that our *Transactions* are the most valuable book of reference which he can get.

I want to tell you of just one man, who will be known to all of you. Rear-Admiral Melville wrote to the Council, at its October meeting, a letter which was read, in which he emphatically opposed the resolution. Mr. Raynal, as a member of the Council, who came to the meeting, was one of those who was converted, and when he returned to Washington and told the Admiral the story and the outcome, the latter immediately gave him a proxy, accompanied with a message to the meeting, that by all means he wished to sustain this resolution.

The unfortunate part of the matter here is, that nine out of ten members of the Society do not know what the actual facts are. It sometimes appears from the somewhat formal reading of our financial reports, and the absence of comment upon them, that our expenditures are not carefully looked after. I have, however, in my hand, a tabular statement, prepared for the Council from the Society's books, running back over a period of ten years, detailing every matter relating to the Society's financial administration, and putting the whole financial history of the Society for ten years under its proper heading. From this list it is very plain that the beginning of the deficiency runs back for several years, although it has been masked in the cash reports by the use of the initiation fees as current income. The great and notable increase which has brought this matter emphatically to the notice of the Council and the membership results from one item this year which came suddenly into our

accounts, by the payment for the plant which is making this room so comfortable to-day, into which so great a number of men have crowded.

The circulars which the Council have issued refer to the question of original research. You are going to have presented to you at this meeting a paper on the "Bursting of Small Fly-wheels." Professor Benjamin has taken a series of small fly-wheels, up to 24 inches in diameter, has speeded them up until he has burst them, and defined positively the speed and stress at which they break. It would seem to me that the limit of size is reached, because it would be a costly matter to go farther. Would it not be a good thing to be able to appropriate funds so that this experimentation might be carried up to wheels of several feet in diameter, so that we might better know about them? Then neither Mr. Fritz nor I would have had to talk so hard as we did at Washington, trying to teach the younger members how to build fly-wheels which would not burst, because the data would be on record in the *Transactions* to enable every man to know what he was doing.

I hope the resolution will prevail. It is my belief that it would have prevailed at once if it could have been possible to bring to the notice of all members whose votes will be deposited here to-day the arguments in favor of the passage of the resolution; but it is the absent fellow whom we cannot inform who has got to be recognized. I hold in my hand proxies, one of which instructs me to vote against the resolution. True to my trust, I must put in the adverse vote, but I know that when this man hears the facts he will say hard words because I didn't tear up his proxy.

Again, in many letters the argument has been advanced that the members resident within a limit distance from New York should pay the advance in dues. I suspect that some members do not appreciate that a very considerable fraction of the expense of these annual meetings in New York City is borne by the personal subscriptions of the New York residents. These are the same men who would pay the increased dues under the other conditions. We come to New York every year, while to the other cities you go at considerable intervals. You are coming to Boston next year, and I hope every man will come and bring his wife, because we are going to give you a good reception; but since you haven't been there before in fifteen years,

it would appear that we ought to be able to afford to go down into our pockets and contribute a little more than the ordinary; even then we do not begin to give the aggregate to the Society which the New York members do, and by which the visiting members benefit.

Mr. H. S. Haines.—When I came to this meeting it was farthest from my mind to speak on this subject. I had received copies of these several circulars from the Council, and had thought of the resolution which had been proposed, and I said to myself, it is not a matter of much consequence to me. If the Council think that it should be done, of course I shall take great pleasure in voting as they would like us to vote.

I had received letters from some of my friends who could not be here, requesting me to oppose the passage of this measure. I have had enough experience in such matters not to make up my mind before hearing the other side, and therefore approached it with impartiality, but from the point of view presented by the Council, that, by increasing our annual dues, we could add to the usefulness of the Society. That is a question upon which we might hold very different opinions. The suggestion was made in the letters which I have mentioned that it was too much to ask of the younger members to assent to this great increase in their dues; that it would be better to furnish less in the way of information and keep within the present income of the Society.

But when I heard the statement just made by our past President, Captain Hunt, I had a feeling which I suppose was shared by every member present who was as ignorant as was I of the condition of the financial affairs of the Society. When I heard Captain Hunt speak of accumulating indebtedness, I felt a sort of sinking in my heart. I am not a recent member of this Society. I have been proud to be connected with it, particularly since I became personally aware last summer of the esteem in which it is held abroad, so that, when I heard a gentleman in whose opinion I have great confidence speak about retrenchment in connection with our affairs, my mind took another turn as to the proposed increase in our dues.

What is the use of discussing the good that can be done by increasing our income from this source? It is not a question of making this Society of greater use, but of maintaining it, of saving it. That seems to be the question which we have to face;

therefore let us not talk about having more research, or more papers, or more anything else. Let us say, "What must we do to be saved?" That is what we should do. Let us view the subject from that standpoint and not discuss bygones or other irrelevant matters. If previous Councils have made mistakes, it has been with the intention of furthering the interests of the Society.

What does the Council want to do in this emergency, and how can we help them? That is the whole question at present. For my part, I am prepared to favor any measure which, upon careful consideration, promises to put the Society where it should be financially, and to enable it to continue the good work which has been carried on for so many years—a work in which it has been earnestly guided by the members of this Council, as well as by the past Presidents, many of whose portraits we see around us on these walls. For their sakes and for the sake of the Society, let us not talk about anything else now but "What shall we do to be saved?" [Applause].

Mr. Henry R. Towne.—It is always well in discussing any question to have both sides of it stated, and in the matter before the meeting there is another side which should be presented, and which I had intended to present somewhat later, but which, it seems to me, can properly come in at this stage of the debate.

I think it will help us if we have some figures and facts, as well as opinions and sentiments. I endorse all of the sentiments that have been uttered. No member has the welfare of this Society more at heart than I, and I think no one appreciates more than I the good work it has done and the still greater possibilities of good work which lie before it in the future; but I am in no sense so pessimistic in my view of its present condition as some of the speakers who have preceded me. We are *not* bankrupt or anywhere near bankruptcy. The Society is in a flourishing condition and very well able to take care of itself. We are, indeed, and unfortunately, in debt; but we have got to get out of it, and we are going to get out of it. It will be a good thing if we can get out of it in one year, and I think perhaps we can and easily; but, if we cannot do it easily, the credit of the Society is quite ample to carry that indebtedness for two or three or four years, if we should need that time in which to liquidate.

Now, let us see what the facts are in regard to this debt. At the close of the Society year of 1896–1897—I will use hereafter the later date of each term as it overlaps a calendar year—at the close of the year 1897 we had an outstanding debt of about $4,200, chiefly due to the printer. At the close of the next year, 1898, the debt had increased to $6,500. At the close of the next year, 1899, it was $7,500. At the close of the next year it stood stationary at $7,500. At the close of the current year it stands at $13,700 approximately. That is an increase for those four years of $9,500, an average in each year of $2,375 that we have run behind; in round numbers, $2,400—or, if you please, $2,500—a year that we have been expending more than we have received. That is what we have got to take care of.

It happens, however, that during last year our expenses were very largely increased by extraordinary conditions; a heating and ventilating apparatus was put into this hall, and some additional wiring was put into the house, and I believe some unusual expenses were incurred in the *Transactions*, which the Secretary can explain if desired. The aggregate of these items accounts for nearly the whole of the increase in the indebtedness during these four years.

We want to clear up that indebtedness. The easiest, and I believe the best, way of doing it will be by a reasonable increase in our dues.

At the time of the Council meeting which has been referred to, on the 31st of October last, I was present, and my name was correctly attached to the statement issued as representing the unanimous opinion expressed at that meeting, but I was in the position which Mr. Boyer has described when he said that not one-third of the members of the Council then present were aware of the financial condition of this Society; I belonged to the other two-thirds. I was not then aware to what extent the Society had entered into debt. I admit the fact with regret and with some sense of mortification, that, as a member of the Council, I ought to have known, but I will come to that a little later. When these facts were put before us, I was converted by the eloquent appeal of Mr. R. W. Hunt, one of our past Presidents, for increased dues, and agreed with the others that, on the whole, perhaps, we had got to make the large increase then proposed. In the month that has since passed I have had time to get together some figures relating to our affairs, and have

changed my opinion; I want to say now that I do not believe we need the large increase of dues for which the resolution before the house calls.

On the basis of last year—the membership has increased since then, but I take last year's figures because it is believed quite generally that if an increase is made in dues there will be a number of resignations, and I want to discount that fact, if it be a fact, therefore I take last year's membership, which amounted approximately to 1,600 members and associates and 500 juniors—the proposed increase of $10 for members and associates would amount to $16,000, and $5 increase for 500 juniors would be $2,500, or a total of $18,500. Why, Mr. President and gentlemen, we should at that rate wipe out our existing indebtedness of slightly over $13,000 in the first year and have $5,000 to the good, and thereafter have $18,500 more income than we have at the present time. I cannot see the occasion, and I do not believe the occasion exists, for any such large increase in the income and for the resulting increase in the burden to our membership; for to a large proportion of our membership, gentlemen it will be a burden to pay $10 in addition to the $15 which is now charged.

My recommendation—and at the proper time I shall put this into the form of an amendment to the pending motion—is that the dues be increased to $20 for members and associates, and $12.50 for juniors, which is just one-half of the amount contemplated in the pending motion, the result of which will be, on the basis of last year's membership, to give us an added income of $9,250. If we secure that added income it will nearly wipe out our existing indebtedness in one year; in addition to which, as Mr. Hunt stated in introducing the motion, certain economies have already been considered and passed upon by the Council which aggregate about $4,000 a year. I accept his figure, and, adding it to the $9,000 increase of income which my suggestion would imply, we get $13,000 in round numbers, which is practically the amount of our indebtedness; so that one year's operations would clear the Society of debt, and thereafter it would have additional available resources of at least $13,000 per annum over and above what it has at the present time.

A statement which has been referred to by Mr. Boyer and Mr. Hunt, prepared in great detail for the information of the Council, shows, when summarized, that the normal expenses

of running the Society's business, grouped into the large main items, are as follows:

For publications, that is, the *Transactions* (I omit the small figures), \$14,000; salaries, \$9,700; meetings, both annual and other meetings, \$2,000; the large catalogue, about \$1,300, and the small catalogue, about \$1,400 (or more than the large one, and that is one of the directions in which economy is proposed); the general printing account, about \$1,900; postage and expressage, nearly \$3,000 (another account which can be reduced); other incidental expenses, \$1,600 or \$1,700; and finally, rent, taxes, interest, and repairs on the building, \$4,500; or a grand total, in round figures, of \$40,000.

Our income from all sources last year was shown to be \$42,000, and the deficit is accounted for chiefly by the extraordinary expenses incurred in the improvement of the plant here, and in the extra expense of last year's *Transactions*.

The addition to that \$42,000 income \$9,000 more of dues will raise it to over \$50,000; while, on the other hand, the operating expenses can be reduced, as the Council has already discovered, and as it proposes to take further steps to accomplish, therefore, Mr. President, I submit that these figures should be kept clearly in view in the discussions which take place at the meeting to-day; and, as I said before, at the proper time I shall move an amendment to the present motion, that the increase in dues be to \$20 for associates and members, and to \$12.50 for juniors. [Applause.]

Col. E. D. Meier.—It is with the utmost regret that I find myself on the other side of the fence from so many of my friends in the Council. The statement made in the report to which we have listened, and further supplemented by the remarks of ex-President Hunt, shows us to be in debt, and it is probably true that this fact was not known to many of the members when proxies were asked for against the amendment. The point which I know was in the mind of many gentlemen who sent adverse proxies was their objection to taxation without representation. If they are not thoroughly informed, they are not properly represented, and I think it is unfortunate that they should not have been told exactly the state of the case with more fulness up to now.

Another point which I should like to raise is the argument for a greater due from the resident membership; that is, for

those who can make use of the headquarters with its privileges. It is a well-known fact that in the larger cities, such as Boston, Philadelphia, Cleveland, Detroit, St. Louis, Chicago, Cincinnati, Denver, and so on, there are other engineering organizations doing essentially the same kind of work that we are doing here. They may not be strictly mechanical engineering societies, since they will include all branches of engineering, but they pay out of their own pockets for their meeting halls and publications. These expenses will average at least $10.00. Hence, it seems to me that the members resident near New York avoid the expense of such a local club, which has to be met by the residents of other cities, and that for this reason they might properly be asked to pay a larger due to this Society. I certainly, while a local member, resident in New York City, would be willing to pay this advance.

It was my knowledge of the feeling of our members in the West and in the other large cities where these clubs exist, which induced me to take up the adverse side of this question. Even if the amendment proposed by Mr. Towne is carried, it would seem to me it should not be brought to a final vote until some later meeting, and that before that final vote the members should all be informed as to the exact state of the case, and for what purpose the increased dues are to be used. I think the proper course for us to take is to vote on the question as it stands, because it was placed before the Society in this form at the Milwaukee meeting. After this has been done will be the proper time to offer an amendment. We all believe in the Society, and I trust that we all feel that the Council has done what it thought to be wisest in the premises. I think, however, that the Council has not been fully informed as to the feelings of the membership resident at a distance. On the other hand, the membership at a distance has not been informed of the difficulties before the Council. It seems to me that when these things have been explained to both parties, there would be little or no difficulty in getting a vote which should be practically unanimous for any such increase as may prove to be necessary. [Applause.]

Mr. A. A. Cary.—Mr. President, when I came here to-day, I had no intention of contributing to this discussion, but Colonel Meier's remarks have brought out some points which appeal to me and which I believe should be carefully considered. From

what has been said I think that we are a little hasty in taking a vote on this question at the present meeting. Would it not be better to have this entire discussion printed and distributed to the membership, while this motion is laid on the table? By this means every voter, especially those not present at this meeting, will be able to study this question carefully and act with his best judgment. There is no doubt at all but that, lacking information, a great many absent voters have voted unintelligently, and with a full understanding of this matter they might reverse their ballots; therefore it seems to me that it is but fair to them to have this action delayed, and thereby avoid putting these absentees in a position to regret the way their ballots were cast.

If a subsidiary motion is in order here, I would move that this proposition be laid upon the table, to be taken up at the next meeting of the Society.

Mr. W. S. Rogers.—Quite a number of years ago, when I became a member of this Society and attended my first meeting, I had an experience with one of the members at that time, which would make an amusing story, and which won for me among those who knew me the pet name of the "hitching post" during my stay at Nashville. I have been wondering whether anybody is trying to make me the "hitching post" in this question of raising the dues. If so, it is a waste of time and energy to try it. I protest against this amendment to-day for one reason and one only. I do not care for my own dues. I will admit right here that the Secretary has to send me four or five notices to square up before I do it, and half the time it is because I want to be contrary with him—I like to get letters from him.

I have been interested all my life in young men. Why? Because I had not the opportunities for education that they have to-day. Every time I have been a proposer for junior membership of a young man who has got through a university or become able to do something, and who is a man who will eventually make his name mean something, the Secretary and our Council have encouraged me to bring him in; they have said, "They are the material we have got to leave behind us to hold us up." We have brought them in, given them no vote, and tell them, "You are not old enough; we know this business, you do not." To-day we are going to adopt the typical

Texas plains plan and say, "Here, we have got you in, and now we are going to rob you, and you can't help yourselves;" and, as one member says, "If you don't like it, get out." Is that honorable engineering? Is it honest business principle?

I want the juniors to stay in. I don't think it right to tax them without representation. Now, I am not wealthy like a whole lot of men of our Society, but if that $13,000 has to be raised, and we have got to have it, I do not want to see the dues go up, for I know what a hardship it will be to many juniors as well as to a number of members who are here to-day; but I will chip in a hundred dollars, and you need not pay interest on it, if my friend Hunt will come up with his, and some of the others of you who can throw away $1,000 to my penny. The Society can pay it back to my children in ten years, without interest, or you can keep it; but let the dues stay as they are, and wipe out the debt and be done with it. By raising the dues you drive out all the members who cannot afford them. There are 130 members here who could easily pay $100 apiece, and thus settle all discussion, and let the Society keep it or pay it back at the end of ten years, without interest; then at once cut off the needless extravagances which are now being practised; let our Council be open and above board with the membership, and tell us what is going on; let them cease trying to play the "paternal" act over us, for we do not want it, neither will we have it.

I do not want to see this amendment put on the table or referred; I want to see it brought to a finish and settled good-naturedly, and after the battle is over we will carry out the wounded. [Applause and laughter.]

Mr. Angus Sinclair.—I am very favorable to the suggestion which my friend Rogers has made. There is nothing easier in the world than getting into debt. We find individuals are very liable to get into debt, and we find corporations and companies and societies get into the same condition; we very often find that those who ought to be the watch-dogs of the treasury, and are not, get blame heaped upon them for permitting the society, the individual, or whatever it may be, buy more than it has money to pay for.

It is not so very long ago that this Society was paying off debts instead of incurring new ones. They paid off a big mortgage for which the Society was responsible, and did it out of

the regular income of the Society; I cannot see why the same thing should not be done now that was done in the past. It will be very easy to increase the dues as now proposed, and yet go on expending so much that in five years we will be in as great debt as we are to-day, and more. [Applause.]

The proper principle to go by is to keep within your income and hold to that—hold grimly to that. We are in debt now. I think the right thing for the Society to do is to make a special effort to wipe out that debt, and then keep within the income. That is what ordinary people do. Well, ordinary people have to pay their debts from the ordinary income; but we can make a special effort, like that which was suggested by Mr. Rogers, and get that money paid off for good, but be mighty sure in the future that you are not spending any more than you are getting in. That is the principle on which we want to spend money.

Mr. F. Meriam Wheeler.—The remarks of our friend Rogers are certainly very amusing; he did, however, seriously touch on one point to which I desire to reply, and that was his suggestion of passing around the hat for some of us to "chip in." We had one experience like that, and I hope it will never be repeated. It was at the time Mr. Copeland was Treasurer, and when we were first confronted with financial troubles. I was then on the Finance Committee, and we decided to make up the deficiency each year by asking for contributions from such members as were willing to be taxed. We had subscriptions to this and subscriptions to that; and while each item in itself was not such a large amount, the sum total was considerable. There were, perhaps, one or two hundred willing members who continued to stand these taxes for a number of years. Finally there were several complaints brought before the Finance Committee, and I suggested it was about time we raised the dues, but I found I was decidedly in the minority. I do not think there was one member of the Finance Committee, not even our worthy Secretary, who favored the suggestion. However, I managed to present a motion at the Providence meeting to increase the dues to $15, which is the amount now in force, and at the following meeting it was carried, as you all know, with little or no opposition. This proved to be an excellent move, for it enabled us to do a good many things which heretofore we could not afford, one of which was the binding of our

Transactions in a more attractive form, so that each member had the same uniform binding for his set of books. It also did away with the numerous charges made on the bills, which it was sometimes difficult to keep track of.

I therefore hope no such idea will now be carried out as suggested by Mr. Rogers. Let us meet our financial obligations in a business-like way, and not by "passing around the hat."

Mr. Worcester R. Warner.—One of our members this morning made a quotation which seems to me to be in point right here. There was a time when our government used to make appropriations for its annual budget, amounting to $500,000,000. Then it grew to $600,000,000; to $700,000,000; to $800,000,000; and finally there was a great hue and cry by the opposition press of the country when the appropriations amounted to $1,000,000,000, and the Congress of that year was called the "billion-dollar Congress." It was the answer which Speaker Reed made at that time which I want to quote. The country was growing larger and stronger during all those years that the appropriations were going up, and it was this circumstance which gave point to Speaker Reed's rejoinder: "It is all right to appropriate $1,000,000,000, because this is a billion-dollar country."

There was a time when we were a $10 Society, and perhaps, also, a time when some of us had to be a little slow in paying those dues. Then we grew in 1891 to be a $15 Society. But if we look over this audience and scrutinize this pocket catalogue of members (which I value very highly and consider to be worth all it costs), I should say that we are not even to be limited to the $25 valuation, because we are more than a $25 Society, and ought not to be asked to get along on only $15. We are a higher grade organization than we were when we started; it is more important to an engineer to be a member of this Society; and for these reasons we should value our membership more highly. With reference to the hardship incident to raising the dues, while I am in full accord with the proposition that we should practise economy, yet, after all, we are proposing to expend only three cents a day. It is too small a sum to talk about as a serious obstacle.

One of the speakers has referred to the standing of an engineer who deserves that name and is worthy to be a member of this Society. If an extra three cents a day is going to make

such a person resign from the Society, my rejoinder is "Pity him." Of course he will drop out and into insignificance.

I am surprised that opposition should ever develop to the proposition to raise the dues. I am willing to accept such an amendment as Mr. Towne has in mind, if it will answer the present needs; but I repeat, that just as we are progressive, just to that same extent will the value of the Society be greater to us. I belong to several organizations in my home city of Cleveland, and I must say that I value them, practically, according to the price I pay for them, which is what they are worth to me. This Society is one of the cheapest to which I belong. While it has been carefully scrutinized from the standpoint of those directly concerned in the industrial processes of the country, I think also the question should be viewed from the standpoint of the professional engineer and of the membership at large in the Society.

In conclusion, I want to express my hope that our dues will be raised to such a point that we can have plenty of money for immediate needs, with some available in the treasury, so that we can do the desirable things and not have to curtail in our publications, our postage, or similar matters, when three cents a day increase of dues would meet all these conditions.

Mr. J. D. Cox.—I came to this meeting with a determination to have a mind entirely unprejudiced on the question of dues, until it should be discussed in the meeting. When the subject was first brought to my notice, I did a little figuring on my own account, and rose with the query in my mind whether any engineer after studying the question would be likely to go to the management of an establishment and advise that the prices to its customers be raised by sixty-six per cent. We are not a corporation formed for profit, so that we do not want to pile up a surplus; we simply want to meet our expenses. We want the expenses to be kept as low as they can and meet the requirements of the members. I think we should first reduce our expenses so as to keep within our income, and then, if better service is desired by the membership, it will be the time to bring up the question of their willingness to pay for it.

I want to express my opinion that life memberships in all institutions are a mistake, and I do not believe that our constitution should provide for one. A proposition to make a life membership fee at $350 is an excellent one for the engineer, because he will,

with a due of $25 per annum, be receiving an interest in excess of seven per cent. While the Society is supposed to invest its life memberships so as to get the advantage of compound interest, it does not seem to me that the figure ought to be put as low as it stands.

Mr. George I. Rockwood.—It does not seem just to me, for one, that the dues of the junior members should be raised, both because these members cannot afford, generally speaking, to pay any more than they now do, and because they have no voting power on the question. It would be a case of "taxation without representation," as some one has already said; but it appears to me, on the other hand, when dealing with the question of raising the dues of full members, all of whom are over thirty years of age, members of a great national engineering society, that it is beside the point to look closely only at the dues that other engineering societies charge. The question we should be considering is, do we want to continue doing as a society what we have been doing, or even more than we have been doing? Do we want to increase the scope of the operations of the Society? Let us have this question discussed. We can afford to pay any dues necessary to manage this Society in the way it ought to be carried on.

I hope we shall not vote to increase the dues of the juniors, but that we shall consider the other question as I have put it.

Mr. John Platt.—I should like to make one or two remarks with regard to what my friend Mr. Warner has said. I quite agree with his ideas, but I would like to refer first to the statement on page 12 of the Report, which begins "the dues of the Institution of the Civil Engineers of Great Britain, whose position in that country is the closest parallel to that occupied by the American Society of Mechanical Engineers in America;" I am sure Mr. Warner will agree with me that the Institution of Civil Engineers is a society to be proud of, and one which is as far advanced as is this one and well able to take care of itself. Now, the statement is made that the dues for members are four guineas a year. That is true to a very limited extent, but only of the members resident near London, and they are a very small proportion of the membership. Again, the associate members of the Institution of Civil Engineers number more than double both the resident and non-resident members of this institution. The dues of the associate members are two and a half guineas. The Institution publishes four large volumes every year, and it is carried on in as

good a way as any society can possibly be. Of course, they have a much larger membership than we have, but they manage to make things go and to make things pay.

I quite agree with Mr. Rockwood, and think that every one ought to do what is necessary and right, and I came here to try and find out what was necessary. I had no idea what it was when I did come; I thought I had gained some little light from the publication of statements in two or three of the technical papers. I think it was a very good thing that some things were brought out by these papers, as, according to Mr. Boyer's statement, it was only late in October that two-thirds of the Council had any idea that the Society was in debt. Well, of course, things had to be done pretty hurriedly after that, and it was not to be expected that the members could be informed of the condition of affairs.

It does seem to me that the expenses should be cut down so that the Society could go on with the dues which are at present paid. I should like to hear something for and against this, and I hope that matters will be ventilated.

Mr. M. N. Forney.—I am opposed to the resolution before the house, for the following reasons: in the first place I do not think the Society is worth $25 to me as I am at present situated. Second, I do not think the Society is worth $25 a year to other persons similarly situated, or to those who are not residents of the city of New York. In the third place, it seems a hardship to impose so high an expense upon many of the younger members of the Society who are not getting very liberal salaries, and who have difficulty in meeting the expenses of this Society and others to which they belong.

There is a very strong feeling against this resolution. I hold in my hand over a hundred proxies instructing me to vote against it, and there are other members who hold a considerable number; for that reason it seems to me that it is impossible that the dues of the members who are not present and who have given proxies should be increased at this meeting. Such members should have an opportunity to vote against this resolution as it stands at present before this Society.

We have heard a good deal here to-day in relation to the indebtedness of the Society, much of which is new to some of us. I think it will be extremely proper at the present juncture that we should take a direct vote on the resolution as it stands, without

amendment, or resolution to lay it on the table; that we should vote that resolution down, and that a committee should be appointed to investigate the condition of the Society and make a full and intelligent report of the actual financial conditions and of the needs for the future. If that was done, and if that was presented to all the members of the Society, those who are absent and those who are here, they would then be able to see the exact reason for raising the dues, and if such reason exists they will be more willing to accede to it. If the resolution is passed at the present time, it seems to me that it will create a good deal of ill-feeling in the Society. I think it will be very much wiser to vote it down now, and leave future action to the future.

Mr. Harry Alexander.—As one of the younger members, I believe that one of the fundamental qualities of an engineer is ambition. I do not believe that any engineer who has that fundamental quality will resign from this Society if the dues are raised. I believe, if the dues are raised, those who have spoken of an intention to resign will seriously hesitate to resign from this Society, knowing well that they have shared an interest in its welfare. I am a young engineer, and working my way up. Before I became a junior of this Society I was very ambitious to be a member. I have striven hard. I believe there are some juniors who may find it a little difficult to pay the additional dues. I also have in mind what Mr. Rogers says—to pass around the hat.

As to the latter, so far as I can see, that will only take care of the matter for the present year. After that we are going to stand where we stand to-day; we want to go ahead. I am young, and want to advance, and I want my young colleagues to do the same.

I have looked carefully through the Report, and have also made some figures for myself, and I have listened to what Mr. Towne has said. As far as I can see, we are in financial distress to a greater or less extent. We evidently have got to meet a deficiency in one way or another. The proper way to do it is to let every member stand his share. True, the juniors are having their dues increased, but only half of what the members and Associates are. It strikes me that if the dues were raised to some extent (I am in favor of the extent proposed) the Society will be able to wipe out its deficiency as well as aspire to do even more; and I honestly

believe that the bulk of the good done by the Society in its pamphlets and periodicals is for the junior members, and especially those who cannot attend. I am a local member, and I believe this is the third time I have been in this house. I do not have the time. I have been engrossed in my work, but I have always had sufficient time to read the papers and at times seriously regret that we do not receive more of them.

I sincerely hope, as one of your younger members, that the motion before the house will prevail.

Mr. F. A. Halsey.—The suggestion made by Colonel Meier, that the dues of the resident members be increased, should not be lost sight of. We have had a voluminous correspondence regarding this matter; and one of the things it has brought out is a feeling on the part of the non-resident members that the resident members should pay more. So far as this feeling is based upon the supposition that the resident members make large use of the Society's house, it is scarcely justified by the facts; but it has nevertheless a good and sufficient basis in the fact that one meeting of every year is held in New York, which meeting the New York members attend without cost. I have never felt that the New York members were entitled to any special credit for their contributions to the entertainment fund. Notwithstanding these contributions, the cost of attending the New York meeting is far less to a New York member than it is to one from a distance. If we are to continue to hold one meeting of each year in New York, then I consider that the feeling of out-of-town members is just, and that the dues of the New York members should be increased.

Regarding the feeling of dissatisfaction with the management of the Society's affairs, it is easy to say that the members at large have no knowledge of the problems of the Council and that they therefore have no right to criticize their acts. The members, however, have the examples of the Civil and Mining Engineers' Societies before them, and they are right in asking why this Society cannot be run as economically as those.

I cannot understand how anyone can object, as Mr. Boyer does, to all members voting upon such a vital question as this, and I do not believe that the technical press needs any defence for having established the right of absentee members to vote by proxy. The Rules lodge the right to change the dues with the members present at a meeting; the right to vote by proxy being, until recently,

not known. The Council were acting under the Rules, and cannot be criticized for doing as they did; but had this matter been decided affirmatively in the manner first contemplated the action would, I believe, have broken the Society in two. The members here have no knowledge of the feeling that was being aroused by the proposition to tax all members by the votes of a few.

Mr. Gus. C. Henning.—I should like to preface my remarks with the statement that the raising of the dues does not affect me, because I am a life member. You also know that I have been a member of this Society for twenty years; that I have probably received more favors at the hands of Councils than any other member—in having been appointed the representative of this Society abroad at Engineering Congresses—and, also, having been a member of the Council, that I may know how the Council operates. Under these circumstances, you will no doubt admit that I have no axe to grind.

Since the proposition before us was made at Milwaukee I have been very much impressed with the matter, and have taken the trouble to investigate the management of several other societies; and I have in my hands official statements of what other societies are doing. I think you will all admit that I have taken the deepest interest in the welfare of this Society and have spent a great deal of my time in studying its interests and in advancing its objects. Therefore I will only say that I am now going to oppose this resolution from none but an honest purpose to improve the influence, work, and growth of the Society. I think that we can do it without an increase of dues. I think we can do it easily; and if I have anything at heart it is certainly to improve and raise the standing of this Society and to increase the benefits to every member.

"The objects of the American Society of Mechanical Engineers are to promote the arts and sciences connected with engineering and mechanical construction, by means of meetings for social intercourse and the reading and discussion of professional papers, and to circulate, by means of publication, among its members the information thus obtained."

This is not done to the extent that it should be done. We publish but one volume, which appears long after everybody has read the papers in the technical press. We do it at an annually increasing cost, and there is no statement or assurance that we will

do it at a less cost hereafter. The larger the Society gets, the greater the cost per member seems to grow.

From 1897 to 1900 it has increased from $14.64 to $18.50. Now, this is something which must be wrong. There is a way of improving matters, and the question is, has any one else found out how this can be done for the same money, or less money, and perhaps do a great deal more than we have done?

While the work of the principal societies in Great Britain and our own country has been laid before you, no one has spoken of the grand work of the Society of German Engineers. That society has annual dues of only $5, but the Society has sections in every district where twenty-five members agree to join under the approval of the Council at headquarters. That Society, by this arrangement, has acquired a membership of 16,000, increasing rapidly at the rate of about twelve or thirteen hundred a year, all engineers in the country joining the same. We profess to be a national society. We are nothing of the sort. There are 40,000 engineers in the country, while but 2,300, or a little more, have become members. We are not a national society. Many of our distant members complain that they are not a part of the Society and do not get the benefits which the New York members enjoy.

We have 585 members living within a radius of 75 miles of New York, that is 150 miles across the circle, every one of whom receives more than those outside of it. Their dues might perhaps be raised, making them "resident members."

I would like to tell you what the Society of German Engineers does. I have before me the annual report, which is also published in their journal issued weekly, and can be given any form. At present it is in this large form, which is inconvenient to be bound in transactions. These weekly issues could all be published in about the same size as our *Transactions*, with folders and illustrations giving all the papers read in the different sections, as well as matters of interest to engineers in general, and sent weekly to all members, instead of six or nine months after each meeting, thus keeping all the members thoroughly posted about engineering progress in this country. Such a publication is a business proposition and should be a source of income, and I do not see how a society such as this can expect to live without a definite source of income. The annual dues are not sufficient to carry out our objects and to instigate original research such as the Council—

certainly while I was a member thereof—had intended to do, and to publish all the latest information of interest to members.

I will give you a few figures from these reports published for 1899 and 1900. The weekly journal of the Society of German Engineers produced a revenue of $297,000 in 1899, which was a net profit of $2,500, after mailing a copy to every member, the number being at that time nearly 14,000. They also spent for their library, $357; donated funds to other societies, $200; made disbursements for changing patent laws; for investigations of steam engines and of materials for smoke stacks; for mechanics schools, for establishing engineer's fees, and for standards of material for pipes, $1,768; they issued Grashof medals at a cost of $233; $750 was devoted to the support of indigent engineers temporarily disabled; $500 was spent for the Paris Exposition; $2,500 was spent for original investigation; and the indebtedness on their three houses was decreased by $3,500. In 1900 a far better showing is made, but I will give only a few of the figures. Receipts of the *Zeitschrift* were $123,000. On special matters, such as reports on prevention of smoke and on standard screw threads—which were, I think, the best standards ever published—$2,100 was expended; for indigent engineers, $1,250; for employees' pension fund, $1,250; expenses at the Paris Exposition were $2,750; and $1,725 were spent for securing valuable papers on various subjects to be presented at meetings of sections; for scientific subjects $1,350 was spent; and $10,300 has been set aside for further research to be undertaken; again, $14,100 has been paid off on buildings, so that these are now nearly free and clear.

I wish to point out that the activity of the Society of German Engineers in all of these matters should be studied before proposing changes of our present Rules, for the purpose of advancing the interests of every member. I think when we see that the Society of German Engineers can do all this work for $5 a year, we shall presently be able to do it with $15, if we start on a proper business basis, and I think there are members in the Society who have already demonstrated that they are capable of running the Society on $15 dues. No one can say that the *Journal* of the German Society does not stand at the head of all serial technical publications, and the work it has done in the way of establishing standards is quite equal to anything done elsewhere. With this extremely successful model before us we ought to do better with our dues of $15 a year than they are doing with $5.

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I wish to state that all the sections of the German Society are created and operate under the advice and control of the Council, and in order that the members may understand thoroughly how this is done, I have prepared a set of rules, which I shall offer later on as an amendment to our present rules, based on our Rules, retaining everything in them which we have learned was satisfactory, and on the German system.

I do not feel that we have arrived at a point where we can stop, and if we do not now take a radical step to put ourselves on a proper business basis, with satisfactory rules, we shall have this fight over again. The Society is twenty years old now, and five years hence we will be just where we are at the present time, if nothing is done to reduce expenses and to provide a regular source of income. The amendments to the Rules of the Society, necessary to give effect to such a modification as is proposed, appear as an appendix to the minutes of this discussion.

Mr. R. H. Soule.—I have been a member of Council for the last three years, and my name was one of those appended to the circular issued by the Council, and therefore, apparently at least, I have been an advocate of this measure; but I have to stand up here and make the acknowledgment that my support of this measure has never been at any time anything more than half-hearted. Although a member of Council, I have the still greater privilege of being a member of the Society, and of reserving my judgment until the last moment and until called upon to deposit my ballot. I am impressed, up to the present time, that the best thing to do is to make the dues $20 a year; but I am not prepared to advocate even that, and I am going to suggest, before I take my seat, what I hope will commend itself to the members as a practical proposition, and an escape from our present dilemma.

I would like to combine some points which have been presented by Mr. Towne, Mr. Sinclair, and Mr. Forney. Mr. Towne is the only speaker, so far, who has given us any analytical presentation of our present condition financially, and I think we may rely on his conclusions, the principal of which were that we were not by any means bankrupt; but that, on the other hand, our credit was fairly good, and that we could survive under the present conditions for three or four years longer. He alluded to the fact that certain economies, which had been already authorized, would result in about $4,000 saving annually; but the Council has other measures inaugurated which will, they believe,

bring about still further economies; so I think we can rely upon a reduction of probably $5,000 a year in our disbursements.

The point made by Mr. Sinclair was that the Council was responsible for this present condition of affairs, and that sentiment I would like to heartily indorse. I have been a member of Council for the three years during which this condition has developed, and therefore I must take my share of the responsibilities. My term of office expires at this meeting, and my shoulder straps and brass buttons are to be torn off; I am going to be reduced to the ranks, so I will get my meed of punishment right away.

Then a point was made by Mr. Forney that he was going to offer a motion later on for the appointment of an investigating committee. I hope that such a motion will not prevail.

Combining these several points, I would like to make this suggestion: that we vote down this amendment, but that we do it with the expectation and understanding that the subject shall be kept alive, and that the Council, if after six months' experience they conclude that they cannot effect sufficient economies to redeem the situation, shall at the spring meeting next May publish a notice of an amendment of the Rules, to be considered at the next annual meeting, a year from now, in which amendment they could repeat what they have recommended now or suggest some modification of it; that will keep the subject open for a year.

I cannot help noticing the earnestness with which this matter has been advocated on both sides, and believing that whichever way it is to go a considerable number of people will be disappointed. Therefore, it seems to me, everything considered, we can well afford to let the main question lie open for a full year, during which time our friends of the technical press, who have been rather severely scored here, I think, can do good work in presenting the evidence they get from time to time. I have the feeling that we can survive this year, and we all know that a concern which has a constantly increasing indebtedness is in poor credit, but a concern whose indebtedness is constantly decreasing is in relatively good credit; and I believe we can demonstrate our position in that way in the course of a year. Therefore I hope sincerely that this measure will be voted down promptly and unanimously, with the understanding and expectation that the Council will at the next meeting, in the spring, introduce this motion again, or a modification of it, in order that it may come

up for discussion a year from now, when the time will be ripe to finally decide it.

Mr. George S. Morison.—There is one point in this discussion which I do not think has been brought forward as prominently as it deserves. This Society has raised its dues once before, in 1891, but at that time it raised them only to the level of those of other societies of like standing. The dues of this Society and those of the American Society of Civil Engineers are $15, which is also practically the rate in the Institution of Civil Engineers of London. I belong to all three of these organizations.

It seems to me, however, that when a society proposes to raise its dues above what other societies pay, it is a step which should be taken only under extreme conditions. To bring its dues to the rank and rate of other societies indicates a healthy growth and need not call for much hesitation. To go beyond this is a very different thing. The *Transactions* of the American Society of Civil Engineers are issued twice. Every paper is sent out in advance, before every meeting, and later with full discussions in a semi-annual volume. While the membership of that society is not much larger than this one, it is now able to accumulate a considerable surplus each year.

Some years ago I belonged to a society of which I am still a member, whose condition, if I have understood the statements of previous speakers, was much like that which appears to face us now. We had fallen into the hands of the printer. The person who was then the secretary of that society was also the printer of its *Transactions*. In his capacity as secretary of the society he collected the dues; as printer he turned his collections over to himself in payment of his own bills, and always showed a balance against the society. What did we do? We elected Capt. Robert W. Hunt president, and the whole matter was overhauled, a radical change was made in the method of conducting the society's work, and the printing was put into other hands. Since then the society has been prosperous. I mention this experience as the sort of thing it is sometimes worth while to remember.

Mr. George L. Fowler.—Like Mr. Forney, I have been opposed to this resolution since I received the first circular in August. On my own motion I wrote a letter to many personal acquaintances in the Society, urging them to use their influence against the proposition, and suggesting that they circulate it among their

own personal friends. The letter called for no reply whatever, and I did not expect to receive any. I thought that possibly the matter would drop there, as far as I was concerned. I was much surprised and somewhat gratified to receive letters from all over the country, from men who are holding prominent positions and men who are quite able to pay the increased dues that are asked, saying that they agreed with me thoroughly, and that they thought it would be a very serious mistake for the Society to increase the dues in the way that has been proposed by the Council.

These men invariably state that they themselves feel perfectly able to pay the $25 a year if it was asked of them, but they know a large number of members of the Society who could not and would not afford to pay it. Together with these letters I have received letters from others saying that they did not consider the *Transactions* of the Society and what they received from it worth more than $15, and a great many have said that they did not consider it worth that.

A large number of these men are holding prominent positions on railways, and they signified their intention of resigning in case the resolution was passed, not that they did not want to belong to the Society, but that they did not consider it worth the money, and they would rather put it into something else. The expenses of every man occupying such a position are already great for *Transactions* of this kind, because he belongs to other societies; it is very rarely that you find a man occupying a prominent position who does not belong to three or four societies of the sort, the value of whose proceedings are fully equal to, if not vastly greater than, those of this Society for his own special work.

Now, I think that the members are of course laboring under something of a misunderstanding in regard to the matter. They did not know that the Society was in debt, and it came upon me this morning, for the first time, like a thunder clap, that we were in that condition. I supposed we were getting along and paying our way. It simply brings out what old Micawber so feelingly expressed, that, "Income, twenty pounds; expenses, nineteen pounds, nineteen shillings, sixpence; result, happiness; expenses, twenty pounds, sixpence; result, misery." We have been expending our twenty pounds and sixpence, and we have got to scale down to our nineteen pounds and a fraction in order to get back into a condition of happiness.

I think the Council has been very remiss that the members have not been informed in regard to the actual status of the Society, and in sanctioning expenses which have brought about this condition of affairs. I have already heard the sentiments which were expressed in the letters received by Mr. Forney stating that they did not consider the value of the proceedings worth more than that which they were already paying. The raising of the dues on a previous occasion has already been alluded to; that was done, as this would have been done this morning had not the proxy matter been brought up, and I think it is due to the technical press entirely that the membership at large had an opportunity to express themselves in regard to this matter in the way they have. As far as I know they have almost unanimously expressed themselves as being most emphatically opposed to any increase in dues, and I have been instructed by a number to vote in that way.

An allusion has been made to the great value of this Society, and a comparison has been made with the increase of dues here and a parallel drawn with the billion-dollar Congress; if my recollection serves me right, the personal taxation was not increased by the billion-dollar Congress, but here we propose to increase our personal taxation at the same time. The resignations, I think, will be numerous if the Society passes this measure, and it will come from men who look upon the matter simply as a business transaction, with a total lack of any sentimental regard for the value which they may receive from this Society from the mere fact of being a member.

There are other societies in the country that are doing fully as good work as we are right along the same lines, whose proceedings are valued fully as highly as ours, the expense of whose membership is very, very much less; and there are many members to whom the increase in dues would be not only oppressive, but almost prohibitory. It is for these reasons that I shall personally vote against and oppose the increase in dues as proposed by the Council.

Mr. William Kent.—I have carefully listened to all the arguments in favor of increasing the dues of the Society, such as that we should pay a larger due and be a greater society, and should conduct researches and do more things than we now do. The only argument which strikes me favorably is that which brings forward the fact that the Society is in debt and must have money.

I want to take this occasion to criticise the method which is used in reporting the condition of the Society each year. It seems to me that to a person like myself, who has every year taken pains to look over the Report of the Finance Committee, the condition which Mr. Towne has spoken of should have been more obvious and that the members of the Council have not been much better informed by these statements than I have. The current report before the Society this morning shows a statement of receipts in excess of the disbursements, and leaves, therefore, the impression that the disbursements are the total expenses of the year, which, apparently, is not the case.

The Report should have had an additional table, showing our indebtedness. I have assumed, in the absence of any tabular statement of liabilities, that the debts were paid each year, and do not think that the explanatory note which refers to the indebtedness in the form of the account with the printer has been as definite as modern methods of bookkeeping would have made clear. I would like to call attention, further, to the two statements which have been made, that we have been running behind about $2,500 a year for the last four years, and, from another speaker, that by a judicious pruning of expenditure something like $4,000 could be saved. This means that, without increasing the dues at all, but by simple, economical administration, the annual deficiency might be changed from $2,500 to a surplus of $1,500. That, I should think, was the thing to do.

Prof. F. L. Emory.—We have heard several speakers give the views of members outside of New York. I am one who lives outside of New York, and will speak for myself. Those who live near New York are supposed to get the advantages of the library and the association and the meetings, which those who are far away do not. The point which I wish to bring out is that many a member away from the city, who must come a long distance to get the local benefits, comes but seldom, and so really gets little except these publications. Now, to me they are worth more than the dues. As a teacher I am trying to bring before young men the knowledge which you have, trying to point out to them what you know; and so far the Society has been very generous to me. Every now and then I get papers to distribute. Any policy which would decrease the usefulness of the Society in that respect would certainly be depriving me of much of its benefit.

As to how the pending question should be worked out, I have not studied. I thought that the Council were looking after that matter, and I believe that the detail can be best worked out by them. As to the policy of the Society, a large society ought to have a large policy, and anything tending to restrict it will be detrimental to it. I sincerely hope that we will adopt no policy which will limit those away from New York in the privileges which they now enjoy.

Mr. George R. Stetson.—I have in my pocket two proxies signed, ready to issue to either party. I am willing, at the present stage of the game, to let each side work in that way. I am satisfied that this question cannot be decided at this meeting without a feeling which it would be unfortunate to have exist in the Society. I think that we have had a very fair discussion of the two sides of the question. I don't know how it could be represented any more strongly in the affirmative, or what further argument could be brought forward in the negative which would be of any great consequence. So far as the membership of New York City is concerned and their increased dues, I suppose it is a fact that it costs every member who lives outside of the 100-mile limit from New York between $25 and $50 a year to attend these meetings. That is something of a tax which we have to pay, but I don't know that New York members are to blame for being more conveniently situated and saving that money. I hardly think it would be satisfactory to them to be taxed as a regular thing for increased dues on that account, although that is a common practice.

I believe that the discussion has gone far enough. I do not believe that it will be of any value to carry it on until afternoon, or to waste the entire day; what I do believe is that there should be a readjustment of the conditions under which this vote is to be taken. I am informed that it is perhaps not proper, under the general Rules, to amend this motion so that the matter of these dues can be carried over to another meeting. I have this suggestion to make, which I will attempt to formulate and will submit to the meeting, that this vote should be taken now, and that the present motion should be rejected unanimously. Then a motion should be made that the Secretary prepare a circular, which should be issued to every member, giving plainly the conditions under which the Society is now placed, with the suggestion that he should vote for either the continuance of the present dues, or

the embodiment of the idea of Mr. Towne that they should be raised about one-half, or the suggestion of the Council that they should be raised to the dues as now proposed; and that every member should be asked to sign either by cross or by yes or no at the end of each one of those suggestions which he prefers to adopt; then we should have a fair expression at the next meeting of the desire of the Society, and under fair conditions; and whatever that decision was I feel that we should submit to it without any feeling of hostility. But I do believe that if the vote is taken and carried through one way or the other to-day, it will operate to the detriment of this Society; and I think there ought to be a fairer condition under which those members who are not able to be present and are in the more distant districts shall have an an opportunity to understand perfectly well what the conditions are under which they vote, and that we should be willing to submit perfectly to the opinions of the majority. I believe that these arguments, with the proper editing, should be sent with the circular, and that you will get as near touching the general membership of the Society as is possible, and will get a vote which will represent more fully than is possible in any other way the desire of the Society; for myself, I am willing to go either way. I think that the discussion could be carried on very much further with but very little value; we have got both sides of it.

*Mr. George W. Colles.**—I have carefully read and re-read the two circulars which have been sent out by the Secretary and Council respectively, relating to this subject; and while I find set forth therein a number of arguments for increasing the dues, I must confess I fail to find the *exact* reason why the increase is demanded. In one place it is stated that the increase is absolutely necessary to cover current expenses, while in another it is assumed apparently that the bulk of the amount represented by the increase will be available for new enterprises, such as research work, indexing, circulating books, and the like; and in another, for a new society building.

It seems to me that these are considerations which should be taken up separately. Thus the matter of current expenses is one which is entirely independent of the question of the desirability of engaging in new lines of work, and both of the question of providing new quarters for the Society.

* Contributed in writing.

The only one of the several considerations put forward which requires our immediate attention is that of current expenses. The other matters can be safely deferred until further opportunity for deliberation and discussion can be had. Taking the figures for receipts and expenditures given by the Finance Committee in their annual reports, and deducting from the latter the amounts representing investment, we find :

Year ending Nov. 15.	Current Receipts.	Current Expenditures.	Surplus.	Number of Members.	Average Expenditure per Member.
1890	$17,443 06	$17,332 84	$110 22	1,220	$14 20
1891	19,805 59	18,958 66	846 93	1,443	13 12
1892	34,193 09	27,271 25	6,921 84	1,569	17 39
1893	34,035 39	25,208 89	8,826 50	1,650	15 29
1894	30,858 53	27,455 92	3,402 61	1,690	16 23
1895	28,908 68	26,833 09	2,075 59	.....	.....
1896	28,869 03	28,378 76	490 27	1,762	16 65
1897	28,309 24	26,537 71	1,771 53	1,823	14 50
1898	32,406 87	31,755 82	651 05	1,861	17 02
1899	34,542 07	32,426 79	2,115 28	1,957	16 59

(The figures for 1900 are not accessible to the writer.)

From these figures we see that not only have the current expenditures per member remained practically constant since 1892, but the total expenditures have also been in every case within the receipts, leaving sufficient margin for the investment of $1,000 or more as a reserve fund, amounting during the aggregate of the eleven years to over $27,000, presumably all convertible into cash. At the end of 1899 the Society held *convertible* assets to the amount of over $53,000, while it had no liabilities other than the customary printer's bill, which was presumably practically covered by the unpaid membership fees. As the Society is now on practically the same footing as regards maintenance and number of members that it was in 1899, it is difficult to see why an immediate increase of 50 to 60 per cent. in the dues, or, in fact, any increase at all, should be required merely to keep it on that footing. The necessity, if such there is, must evidently arise either from some sudden and unexplained falling off in the receipts, or from some equally sudden and unexplained increase in the expenditures. Now, such sudden increase, if merely temporary, is amply provided for by the invested surplus of previous years, and forms no true basis for an increase in the annual receipts *in perpetuum.*

Another question that is left apparently unanswered is, Why should it cost more *pro rata* to run a society with 2,000 members

than one with 1,000? With the same service it ought to cost less—everybody will admit that. Granting that the service has been increased somewhat in the last ten years, it is clear that there are large savings which ought to be made, which would certainly under reasonable suppositions more than offset the increased service. The charges for the Society headquarters, for office force, for library, for typsetting and the like remain nearly fixed and independent of the number of members. Consequently the cost per member of running the Society should decrease instead of increasing. Yet the Secretary's figures show that the direct and indirect expense for publications (?) per member has increased from $14.64 in 1897 to $18.50 in 1900, an increase of 26 per cent. It would seem that this increase calls for explanation.

The question of the desirability of devoting a certain portion annually of the Society's income to engineering research, as well as the question of providing a new home for the Society, are each matters which should be considered by themselves alone, and it seems to me that before anything at all can be done, before any rational conclusion can be reached by the voting membership, we should have plans, specifications, and estimates of just what is proposed and what sum is required, and then only shall we be in a position to decide intelligently whether or not the appropriation shall be made.

It is by no means my desire to impugn the wisdom of our honored Council as expressed in their decision, for which they undoubtedly have what are, to them, excellent reasons. But it is my belief that a matter of this sort, involving the expenditure of a large sum of money, ought to be decided by the membership alone, for only they can know how they want the Society conducted.

Nor have I any notion of raising the poverty plea, for there are surely few among us who would refuse the amount necessary to maintain our Society's rank and reputation, and fewer still who would begrudge their annual contribution. I think we are rich enough to say that the Society shall have what it needs for its maintenance to any reasonable amount. But really the question as to how much the individual members may feel the burden (which, as our honorable Secretary duly says, is but three cents a day), is entirely from the point, and so is the question as to the intrinsic worth of the membership. These arguments have nothing to do with the cost of running the Society, and merely tend

to obscure the real issue. The question of the expenditures or membership dues of English societies has little relevancy; but if these be taken as a guide, then the dues of our Society should be left as they are, for the regular fee of members of the English Institution of Civil Engineers (the society cited in the circular) is $15 per annum, which is increased to $20 only for residents of London and vicinity.

For the reasons above given I must record my vote in opposition to the proposed increase of dues at the present time. I do not wish to be understood as absolutely disfavoring any future proposition to that end, however, but merely until good and sufficient reasons therefor shall have been clearly set forth, together with a clear and definite plan of procedure, which can be intelligently discussed, and after sufficient time for due deliberation and discussion thereof shall have been given to the whole membership.

Mr. Towne.—It is almost one o'clock. We have devoted the morning to this discussion, and I agree with Mr. Stetson that we have probably had as much talk as can profitably be expended at this time. There is evidently a division of sentiment among the membership on the question, and it is still more evident that the members, from the Council down to the last junior, have not at the present time sufficient knowledge of the facts upon which to base intelligent action. Mr. President, I am going to move, and I now make the motion, that the resolution before the house be laid on the table. I am not going to qualify that motion, and I hope it will not be amended. If laid on the table it can be taken up by the Society at any time it pleases. I hope it surely will be taken up at the next meeting in the spring. It could be taken up at a special meeting if necessary. I do not apprehend any difficulty in the financing of the Society during the interval. I am one, and I know there are others, interested in the Society, who will say that it shall not lack for the funds necessary to carry over that period.

The suggestion made by the last speaker that the information needed should be put before the membership of the Society at large is admirable and should be done; and I think it requires no motion to accomplish that. I am sure I voice the sentiment of the Council that as soon as it has that information it will gladly extend it to the whole membership, and will feel its obligation to do so. Therefore, as we have devoted half the day to our discussion,

and have reached a point where, apparently, all are contented to take a vote on it, and also where, apparently, if a vote were taken by ballot it would probably be adverse, and certainly would take a long time—some hours—for the tellers to count and record, in order that all that time may be saved and our session proceed to other business, I hope my motion to lay on the table will be seconded and will prevail.

A Member.—I second that motion.

A considerable discussion took place at this point as to the advisability of laying the question on the table when proxies had been specifically issued to so many members with a definite intention that they should be used at this meeting. While the proxies give a right to vote at an adjourned meeting, yet they also give the right to vote on the question later, and the decision of the action of the meeting on the question to lay it on the table would be as embarrassing as to bring up the principal question. The discussion was finally terminated by a withdrawal of the motion to lay on the table and by the motion of the previous question. This carried with it the vote by ballot upon the original proposition to amend, and on being put by the chair was unanimously carried. The chair appointed Messrs. L. R. Pomeroy, F. J. Miller, and H. H. Suplee tellers. Instructions were given that each proxy required a ballot, to be signed with the name of the sender of the proxy and by the name of the member holding it. The proxy was to be pinned to the ballot.

The meeting thereupon took a recess in order that the polls might be open a sufficient time, and adjourned until three o'clock, at which time the polls were to be closed.

After the recess President Wellman called the meeting to order.

Mr. H. R. Towne.—In view of the fact that before the recess and during its continuance suggestions have been informally made for a committee to be appointed to investigate the financial condition of the Society, it would seem fitting that I should report to the meeting that the Council, at a meeting yesterday, passed resolutions authorizing the appointment of a committee to investigate the finances of the Society and examine its system of accounts. It was the object of the appointment of this committee that the Council should be more easily able to scrutinize the statements of the condition of the Society at any time, and inaugurate the practice of placing statements of this sort before the members annually.

Mr. Albert A. Cary moved that a resolution be passed approving the action of the Council.

A resolution proposing that a special committee should be appointed to make a general investigation of the Society's expenditures and report at the next regular meeting was not seconded.

Mr. C. W. Baker gave notice of his purpose to present the following amendment to the Rules, to come up for consideration and action under the present provisions of Article 45.

Strike out Article 45, and substitute in its place the following:

At any regular meeting of the Society any member may propose in writing an amendment to these Rules, *a copy of such amendment having been filed with the Council at least ten days before the opening of said meeting. Such amendment* shall be taken up by the Society at a following session of the same meeting and shall be subject to discussion and amendment and to final acceptance or rejection by a majority vote of the members present and voting. If it is finally accepted, it shall be submitted to a letter ballot of the entire voting membership of the Society, such ballots to be sent out at the same time as the next succeeding ballot for the election of members. A majority of the ballots cast shall adopt or reject the amendment.

Mr. C. W. Hunt called attention to the fact that the proxies used at the present meeting are in accordance with the corporation laws of the State of New York, and that no provision of the Rules arranging for a letter ballot could prevent any member from appointing a proxy to act for him at any meeting of the members of the Society, and that the holder of such proxy could vote on all motions coming up before the meeting.

Mr. Baker, in reply, stated that his amendment was intended to do away with the inducement to use the proxy as a method of expressing opinion or desires, by making all changes in the Rules come of necessity before the entire membership by the letter-ballot method. This would not prevent the use of proxies if members wished to give them or have them used, but would avoid the probability of their being used, and avoid also the delay in taking the vote, which had been made evident at the present meeting. Under the provisions of that amendment Mr. Baker asked that the meeting give its sense as to whether an amendment of this sort should be adopted. On motion it was resolved that it was the sense of the meeting that this amendment should be adopted, and in that form the resolution was passed, with the understanding that it was an informal vote to obtain the opinion of the members present on the question involved.

On motion the meeting adjourned to 9.45 on the morning of Thursday, December 5th.

APPENDIX.

Amendments Proposed by Gus. C. Henning.

PROPOSED STATUTES OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

I. Name, Corporate Residence, Objects, and Organization of the Society.

Article 1.

The name of the Society shall be "The American Society of Mechanical Engineers."

The corporate residence shall be New York, N. Y., U. S. A.

Article 2.

The objects of the Society are the intellectual coöperation of American Engineers for the benefit of manufacturing industries and the enhancement of the profession.

The attainment of these objects shall be furthered :

(*a*) By meetings and transactions of the Society and of its sections.

(*b*) By the publication of a journal.

(*c*) By circulating journals, reading-rooms and libraries.

(*d*) By announcing prize studies, and encouragement of investigations for the determination of important engineering questions.

(*e*) By assisting the publication of engineering literature.

(*f*) By other procedures tending to advance the objects of the Society.

Article 3.

For the better realization of its objects, the Society shall create local sections among its members.

II. Funds.

Article 4.

The available means at the disposal of the Society for the advancement of the objects stated in Article 2 are :

(*a*) The Society House, value ——

(*b*) The Fund, value ——

(*c*) The Library and Literary Fund, value ——

(*d*) Receipts from publications ——

(*e*) Initiation Fees, Annual Dues, and Life Membership Dues ——

(*f*) Other sources and donations ——

III. Membership.

Article 5.

The Society shall consist of Honorary Members, Members, Associates, and Juniors.

Article 6.

(*a*) Full membership is open to all persons not less than thirty years of age so connected with engineering as to be competent as designers, constructors, or technological managers, and to instructors in engineering who have taught for at least five years.

(*b*) Associate membership is open to all persons at least twenty-six years of age, having the other qualifications for membership, who shall have been so connected with engineering as to be competent to take charge of work *and are actively interested in engineering.*

(*c*) Junior membership is open to all persons who have such engineering experience as will enable them to fill a responsible position, or who are graduates of an engineering school.

(*d*) Honorary membership may be offered to not more than twenty-five persons of acknowledged professional eminence.

Article 7.

Membership begins upon payment of initiation fees and the first annual dues. All Honorary Members, Members, and Associates shall be equally entitled to the privileges of membership. Juniors shall not be entitled to vote nor hold office in the Society.

Article 8.

Same as No. 9, present Rules.

Article 9.

A candidate for admission to the Society (same as No. 10).

A candidate for admission to any section of the Society shall make application to the section he proposes to join in the same manner, and his election shall then be approved by the Council of the National Society upon recommendation of his section.

Article 10.

Same as old No. 11 ; and add : referees for candidates for sections shall make similar communications to the Section Councils.

Article 11.

Same as old No. 12, and add same for Sections.

Article 12.

Same as old No. 13.

Article 13.

Same as old No. 14.

Article 14.

Same as old No. 15.

Article 15.

Same as old No. 16 ; but voted upon by members of Advisory Council.

Article 16.

Same as old No. 17.

Article 17.

Same as old No. 18.

Article 18.

Membership ceases, besides by death :

(*a*) By resignation, in writing, to the Secretary of the National Society.

(*b*) As in old Article 19.

(*c*) By resolution of Advisory Council, in case a member violates his duties as a member, or has shown himself unworthy of the respect of his fellow-members.

(*d*) By loss of citizenship because of legal decisions against him to that effect.

Or exclusion is to be served on the respective person by a letter from the Council.

IV. Management of the Society.

Article 19.

The affairs of the Society shall be managed by—

(1) The Council (Article 20).

(2) The Advisory Council (Article 23).

(3) The General Meeting.

The management of the business of the Society shall be entrusted to a salaried Secretary-Treasurer, and shall be located in New York City.

Article 20.

The Council shall consist of the President of the Society, two Vice-Presidents, and three Managers.

Article 21.

Members of the Council shall be nominated from the general membership by the Advisory Council, and elected by the members present at the Annual Meeting. At each Annual Meeting there shall be elected the President, one Vice-President, and one Manager; thus making the terms for President one year, for Vice-President two years, and for Managers three years.

Members of Council may not be reëlected for the term immediately following. The Annual Meeting may, however, remove this limitation as regarding one Manager and designate the latter as elected for an indefinite period. This Manager shall be designated as the "Curator," and he shall be considered as reëlected, provided no motion for a substitute has been offered. Should, however, a substitute be offered, an election shall be held.

Should no Annual Meeting take place, the members of Council shall hold over.

Article 22.

Should a Member of Council die or resign before the expiration of his term, the Council shall elect another member to fill the unexpired term of this Councillor. Such election by the Council may be by letter ballot.

The Council directs the Society, and represents it when dealing with governmental bodies or private persons, in all matters, and also in business in which the laws require a power of attorney to be properly represented.

Documents which bind or obligate the Society financially shall be signed on behalf of the Society by the President and a second member of Council, and countersigned by the Secretary-Treasurer.

Article 23.

The Advisory Council shall consist of the Council and delegates of the sections.

Article 24.

Every section has the right to elect one delegate for each 250 members, to act as representatives on the Advisory Council, each with a single vote. These representatives and their substitutes shall be elected annually. In case any delegate resigns or leaves the section he represents, it shall immediately elect a substitute.

Article 25.

The Advisory Council, but especially the Council, shall make it their duty to advance the interests of the Society in every manner permitted by the Statutes.

The Advisory Council decides all matters delegated to it (Articles 8, 18, 21, 27, 31, 33, 43, 48, 49, 53, 54), submitted by the Council or by the General Meeting.

Article 26.

The Advisory Council shall meet at least once a year, in any case, in connection with the General Meeting, and at the place where it is held, and also upon request of the Chairman, which may be issued at any time upon the written request of one-fourth of all members of the Advisory Council, and within eight weeks of such request. The place of meeting in such case shall be decided by the Chairman. The Chairman may, when it appears suitable to him, call a letter ballot of its members when the Advisory Council has not assembled in meeting.

Article 27.

The President of the Society calls and presides at the Council meetings and those of the Advisory Council, as well as at General Meetings. With the consent of the Advisory Council, he has the right of calling extra General Meetings in urgent cases, at designated places. Council meetings shall convene upon at least eight days' notice, those of the Advisory Council upon at least fourteen days' notice by registered letter, addressed to every member, stating the order of business. The General Meetings shall be called as in Articles 42 and 43.

Article 28.

Five members of the Council shall constitute a quorum ; one half the number of members of the Advisory Council shall constitute its quorum. In all voting a majority shall rule ; if a tie exists the Chairman shall cast the deciding vote or, in case of elections, the deciding ballot.

Members of Council may vote by letter transmitted to the Secretary, if unavoidably absent. Minutes of the proceedings of these meetings are to be kept, which are to be signed by the Chairman and the Secretary appointed by the Chairman after approval by the meeting, and then to be filed in the archives.

Article 30.

The fiscal year shall begin on January 1st. The Annual Meeting shall select two Auditors and two substitutes from those members not already holding office, whose duty it shall be to audit all books and accounts for the current year. Should no Annual Meeting take place in any one year, the previously elected Auditors shall continue in their offices for that year also.

Article 31.

Members of Council and officers shall be those mentioned in, and to be elected as in, Articles 20, 21, 23, omitting the Treasurer and the Secretary.

The Council shall elect by a majority of votes a Secretary whose duty it shall be to keep its minutes without compensation. The offices of the Councillors shall be honorary; the Curator alone shall receive compensation previously agreed upon by the Council and included in the annual estimate of expenses.

Article 32.

The Council shall supervise the finances of the Society. Complaints relating to the actions of the Secretary-Treasurer are to be submitted to the Council.

Article 33.

The Secretary-Treasurer shall be elected by the Advisory Council, which also shall arrange all contracts and salaries covered by the annual estimates in conjunction with the former. The Secretary-Treasurer shall look after the affairs of the Society under directions from the Council. Should he become disabled he shall be replaced by action of the Council.

Article 34.

The Secretary-Treasurer shall have a consultative voice in all meetings of Council, of Advisory Council, and of the representatives of Sections (Article 45).

Article 35.

The duties of the Council and of its members of the Advisory Council and of the Secretary-Treasurer, when not covered by these Rules, shall be regulated by special resolutions. Such special resolutions shall be ratified by the Annual Meeting.

V. Rights and Duties of Members.

Article 36.

Every Member shall be furnished gratis with a copy of the Statutes and of the Rules, upon his admission to the Society, and of changes when made therein.

Article 37.

Every Member, Associate, and Junior shall pay initiation fees as at present. (See Articles 18 and 19.) Of these initiation fees $10 shall be paid to the sectional Society which the Member or Associate first joins. Juniors shall pay $5 to same fund. Should a member desire to rejoin the Society, the Council shall decide the possible request for remission of initiation fees.

Article 38.

Each Member and Associate shall pay annual dues (as in Articles 18 and 19 of Rules). Of these amounts, Members and Associates shall pay $5 and Juniors $3 to the section they first join. Life Membership remains same as in Article 18. Should any person be a member of several sections, then his share of annual dues shall be paid to that section which he may select.

Article 39.

The General (annual) Meeting may change the amounts stated in Articles 37 and 38, by a two-thirds vote, provided that written notice of the proposed amendment shall have been given at a previous meeting.

Article 40.

Every Member shall have the right of one vote at every General Meeting and is eligible to every office.

Article 41.

Every Member is entitled during the period in which he pays his dues to one copy of the publications of the Society free of charge. It is the duty of every member to send his postal address, as well as any changes thereof, to the Society headquarters.

VI. Meetings.

Article 42.

There shall be one Annual Meeting and at least one other General Meeting each year. The Annual Meeting shall always be held at New York; General Meetings shall be held at places to be selected by the Council and announced at the preceding Annual Meeting.

Motions to be discussed at these meetings shall be handed to the President, in writing, at least ten weeks, and notice thereof shall be sent to the members at least two weeks in advance of such meeting. The order of business shall be distributed among the membership at least two weeks in advance of every meeting.

Should these motions relate to the dissolution of the Society, they shall be presented in writing at one meeting, discussed at the next, and thereupon acted upon by the entire membership by letter ballot.

Article 43.

Additional General Meetings shall be called by the President upon the written request of at least one-third of all the sections, and only after at least one month's notice to all members.

Article 44.

Every such General Meeting shall have power to adopt resolutions, provided a quorum be present, regardless of the number of members present. In a General Meeting in which the dissolution of the Society shall be discussed, at least one-fourth of the total membership shall be present to make its action binding. Should this not be the case and the motion to dissolve not be withdrawn, then another meeting shall be called within three months, with the same order of business, upon two notices, one issued two weeks and one a week previous to such meeting. This meeting shall then have power to act regardless of the number of members present, and this fact shall be specially mentioned in each notice of such meeting.

Article 45.

All questions relating to the internal affairs or the finances of the Society, its rights, or obligations, are subject to the action of the General Meeting, unless otherwise specially provided for in the Rules. All other questions not relating to these matters shall be determined upon decision of the Council if it does not consider itself competent to decide them, by obtaining the views of the sections, or by representatives of the latter in meeting assembled. Members of Council shall have voice and vote in these meetings, to which experts and interested parties may be invited by the Council to present their views. The first sentence of this Article shall not affect actions taken by the Council under Article 25.

Article 46.

The same rules relating to meeting of the Advisory Council shall apply to calls, management, and actions of meetings of representatives of sections, and to the proportion of representatives at the same (Articles 25, 26, 27).

Article 47.

Subjects for action at the Annual Meeting are:

(*a*) Reception of annual accounts, and approval thereof.

(*b*) Adoption of annual estimates of expenses.

(*c*) Provision for unusual expenses.

(*d*) Election of Council, Auditors and Honorary Members.

(*e*) Reports, discussions, resolutions relating to the affairs of the Society, especially regulations of annual dues.

(*f*) Papers on and discussion of important engineering subjects and of technical sciences.

(*g*) Amendments to the Rules and possible dissolution of the Society.

(*h*) Selection of the next meeting place.

(*i*) Visits to engineering establishments.

(*j*) Social meetings for purpose of cultivating acquaintance among members.

Article 48.

All resolutions to be acted upon by the Annual Meeting shall previously be discussed by the Advisory Council and presented by it for adoption or rejection in proper form. Amendments suggested during such meeting shall be treated in similar manner.

Article 49.

Resolutions other than those relating to changes of Rules or the dissolution of the Society may also be brought up for discussion, even when not brought to the notice of members as specified in Articles 42 and 43, but only in case their urgency be recognized by a majority of the members present. Such resolutions also require the approval of the members present and of the Advisory Council before adoption.

Article 50.

Amendments to the Rules require a two-thirds majority of members present at an Annual Meeting for their adoption.

Article 51.

Members of Council shall be elected separately, by secret ballots, the President having the deciding vote. The election of auditors shall be by one ballot containing all names.

Article 52.

Minutes are to be kept at all Annual Meetings, which are to be approved by the members of Council present and three members of the Advisory Council designated by it, drawn up by them, and shall be filed in the archives.

SECTIONS.

Article 53.

These Rules of the Society are binding in all its Articles on the section. The sections are bound to further the objects of the Society, as laid down in Article 2, in their respective districts. The sections are managed by Councils. The Coun-

cillors, the delegates to the Advisory Council (Article 25), and representatives of sections (Article 45) are elected according to the By-Laws of each section. These By-Laws shall be approved by the Council, which procures the decision of the Advisory Council in doubtful cases.

Membership in a section may be regulated by election according to its By-Laws, even in cases where applicants are already members of the Society. Likewise these By-Laws provide for exclusion from the sections.

Article 54.

At least 40 members shall be necessary to form a new section, as well as the approval of the Advisory Council.

Article 55.

Every regular member of a section is at the same time a member of the Society. Special members of sections neither possess rights nor have they any duties toward the Society.

VIII. PUBLICATIONS.

Article 56.

The publications shall provide opportunities to keep track of progress of industries and technical journals, and to discuss scientific questions of interest.

Article 57.

Rules relating to the appearance and editing of the publications shall be made by the Annual Meeting.

IX. RESERVE FUND.

Article 58.

The Society shall create a reserve fund of at least $, and shall replenish it, should it at any time be reduced below this figure. The amount of this fund may be increased by resolution at a general meeting.

This fund is to be created by—

(1) The Society's share of initiation fees (Article 37).

(2) Ten per cent. of the Society's share of annual dues (Article 38).

(3) By interest on funds in hand.

(4) By donations and Life Memberships.

Whenever this fund has been created, items as per 1, 2, 3, and 4 shall be devoted to developing the working capital.

The reserve fund is to be used for current expenses of the Society whenever the working capital and receipts are insufficient.

RULES

Governing the Management of the Society under the Statutes.

CONCERNING III. MEMBERSHIPS.

No. 1. Notice of candidacy for memberships in the Society shall be sent to the Council of the section, should the person desire to join such, which sends immediate notice thereof to the Society headquarters, otherwise to the headquarters in New York, direct, and which shall enter the name upon the rolls immediately after election.

No. 2. Such enrollment shall be published in the publication, and a membership certificate furnished the candidate after he shall have complied with Articles 37 and 38. Such certificates shall be signed by the President and the Secretary-Treasurer.

No. 3. Notice of exclusion of a person from membership shall be signed by the Council (Article 18).

No. 4. Notice of election to Honorary Membership and certificate of same shall be issued by the Council.

CONCERNING IV. MANAGEMENT OF THE SOCIETY.

No. 5. Council meetings shall be called upon at least eight days' notice, those of the Advisory Council upon fourteen days' notice (Article 26). A detailed order of business shall be sent to the members with the call. Orders of business of the Advisory Council shall be prepared by the Council. Matters relating to the Society, to be presented by members of the Advisory Council, shall be previously submitted to the Chairman.

No. 6. Two Recorders are to be appointed for meetings of the Advisory Council (Article 27). Each member thereof shall promptly receive one copy of the minutes. These minutes may also be taken down by a stenographer and extracts thereof approved by the Chairman and then published. Such stenograms shall be preserved with above records.

No. 7. These extracts to be published may be joined to limiting resolutions adopted by the Advisory Council.

No. 8. Official communications among the Council shall be by circular letter. Each member of Council shall have the right to request the issue of such letter by the Chairman.

After its circulation the letter shall be returned to the Chairman for further disposition, or to the Secretary-Treasurer in case its execution by the latter is a matter of course, in case of unanimous approval of election to the Society. Any expressions of opinion of individual members of Council shall be transmitted to all other members.

No. 9. The Council shall meet as required in any case previous to the Annual Meeting, as well as in connection with meetings of the Advisory Council and General Meetings. A Council meeting may be called upon request of a majority of its members, or by its Chairman.

No. 10. Besides the Secretary-Treasurer, who assists at meetings of the Council and Advisory Council (Article 34), other members, experts, and interested persons may be requested to be present to discuss special questions which may have been submitted.

No. 11. Complaints regarding omissions or commissions of the Council, which may be sent to the latter direct, shall be submitted by the Chairman to the Advisory Council for action at its next meeting, in case his personal explanations have not been satisfactory.

No. 12. It shall be the duty of the Curator, as permanent member of the Council, to maintain surveillance over the entire activity of the Society in compliance with the statutes and traditions. Should the Society fail to elect a Curator (Article 21), the Council shall assume his duties and divide them among its members.

No. 13. The Secretary-Treasurer shall look after not only those matters mentioned in these Rules, but also all Society business not otherwise provided for; editing all publications, arranging and managing financial matters, and examining all bills. He shall present to the Council for its examinations and approval the

financial reports for the current year, as well as a financial estimate for the succeeding one. This estimate shall contain an item for incidental or unforeseen expenses. Annual financial statement and estimate of expenses shall be published in the *Journal* in advance of the annual meeting.

No. 13A. The Secretary-Treasurer shall be responsible for the proper execution of the resolutions of Council relating to investment, care of and management of the Society funds, as well as the disposition thereof according to the Statutes and the annual estimate.

No. 14. Disbursement not provided for in the estimate adopted at the Annual Meeting shall be passed upon by the Council. Should unforeseen circumstances materially alter the adequacy of the estimate, the Secretary-Treasurer shall notify the Council in ample time that it may take proper action.

No. 15. Official correspondence without the membership, such as memorials to governmental functionaries, etc., shall be signed by the President and the Curator, or their deputies. Should the Secretary-Treasurer also be interested in these communications he shall sign them as well.

No. 16. Headquarters shall take care of all correspondence between the Council, the Advisory Council, and the sections.

Communications between the Council and the sections shall be signed by the President and the Secretary-Treasurer, or their deputies.

The Secretary-Treasurer shall sign all letters and papers under a stamp :

The A. S. M. E.,
by the Secretary-General.
[Signature]

Editorial letters relating to the publication of the *Journal :*

The Editor of the *Journal,* A. S. M. E.,
[Signature]

No. 17. The Secretary-Treasurer shall assist the Council in preparing and carrying out its resolutions, and call its attention to matters which require its attention in order to protect the interests of the Society.

No. 18. The Chairman has the privilege, upon an arrangement with the Council, to grant leave of absence to the Secretary-Treasurer from time to time, whose application, therefor, shall make provision for handling necessary Society business during his absence.

No. 19. When certain matters in the care of the Secretary-Treasurer shall be turned over to other persons with his consent, they shall act only in his name and under his responsibility.

No. 20. Complaints relating to acts of the Secretary-Treasurer shall be submitted to the Council. The latter shall decide after hearing the Secretary-Treasurer. Appeal may be taken from the decisions of Council to the Advisory Council.

No. 21. Assistants and employees provided for in the estimate shall be secured under written contracts by the Secretary-Treasurer, to be approved by the Council.

The Council shall also approve of the duties of the employees and of their hours of labor, which they shall then observe.

The Secretary-Treasurer may grant his employees up to ten days' leave ; any leave beyond this term shall be approved by the Council. In case of disability for a period greater than one month, the Secretary-Treasurer shall report the fact to the Council, with propositions for a possible substitution.

No. 22. Contracts for materials required by headquarters shall be approved by Council.

CONCERNING V. RIGHTS AND DUTIES OF MEMBERS.

No. 23. Requests to omit initiation fees upon repeated admission to the Society (Article 37) may be granted when resignation was caused either by removal to a foreign country, upon quitting the profession, long-continued illness, or loss of means of support.

No. 24. Names of members of Council of the Society and its sections, as well as their representatives in the Advisory Council, shall be published in the *Journal* at the beginning of each year; a separate copy of these lists shall be sent to every member of the Advisory Council. Each member of the Society shall receive a complete list of members gratis, and this shall be reissued annually after correction and amplification.

CONCERNING VI. MEETINGS.

No. 25. The Annual Meeting shall instruct one or more sections in whose vicinity the next General Meeting is to be held to elect a Local Committee.

No. 26. Such Committee require the approval by the Council of their proposed dates of meetings and entertainments.

No. 27. Such expenses as become necessary for objects of the meetings (Article 47 *a–i*), or which serve for representation of the Society, are paid by the general fund, while all other expenses incurred by entertainment shall be paid by the participants.

No. 28. The previous General Meeting shall provide a fund for the legitimate expenses, which shall be placed at the disposition of the Local Committee; should it seem likely that this sum be exceeded through unforeseen circumstances or in the interests of the Society, the increase shall be submitted to the Council for its consideration.

No. 29. Keeping the records of General Meetings is obligatory upon the Secretary-Treasurer, unless the Chairman provides otherwise. The proceedings shall also be stenographed, and then be published in the *Journal* with all other matters of interest in a form as directed by the Council. The records of proceedings made as in Article 52 shall be filed in the archives.

No. 30. Expenses caused by the object of meetings of the Council, the Advisory Council, or representatives of sections (Article 45) shall be met by the General Fund.

CONCERNING VII. SECTIONS.

No. 31. By-Laws of sections, as well as their amendments (Article 53), shall be first submitted to the Curator for his opinion and then to the Council for its approval.

No. 32. The consent of the Advisory Council to the constitution of a new section (Article 54) may upon request of the Council be obtained by correspondence. Should the latter not be in session, the opinion of the Curator should first be ascertained.

No. 33. Communications of a section to others relating to affairs of the Society shall also be sent to the Council at the same time.

No. 34. Each section shall send the Secretary-Treasurer, one month in advance of the Council Meeting, are port of its condition and activity; the Secretary-Treasurer shall publish a compilation of these reports in the *Journal* previous to such meeting.

No. 35. In order that the lists of officers of sections for the coming year (No. 24) may be published in the annual report thereof, the Councils of sections are required to send their lists to headquarters before the end of the year, and also all changes which shall have taken place within the year.

No. 36. Sections may admit to their meetings, under the By-Laws approved by the Council, participants or special members, who shall not have votes in matters concerning the Society.

No. 37. All correspondence and delivery shall be prepaid.

Third Session. Thursday Morning, December 5th.

The President announced the report of the tellers appointed to scrutinize and count the ballots upon the question discussed at the previous meeting, concerning the amendments to the Rules. The report was as follows:

December 4, 1901.

The undersigned, tellers, hereby report that there were cast

No	647
Yes	191
Irregular	36
Total	874

on the proposed amendments to the Rules.

Fred J. Miller,
H. H. Suplee,
L. R. Pomeroy.

The Chairman therefore announced that the proposed amendment was defeated, but that under the tenor of the discussion of the previous day it would come up again in an amended form at a later convention.

The Topical Discussions deferred from Wednesday morning's session were then taken up.

"Cost of Running Trains at High Speed;" "Some Peculiarities of Springs;" "The Linvolpon System of Units;" and professional papers as follows: "A Portable Accelerometer for Railway Testing," by F. B. Corey; "A Bonus System of Rewarding Labor," by H. L. Gantt. The participants in debate were Messrs. Wilfred Lewis, Geo. L. Fowler, L. R. Pomeroy, H. S. Haines, M. N. Forney, C. G. Barth, Stephen W. Baldwin, A. A. Cary, A. Kingsbury, Brashear, Whittemore, Thurston, Halsey, and Day.

Fourth Session. Thursday Evening, December 5th.

The discussion of Mr. Gantt's paper was carried forward to this session, in which Messrs. C. H. Buckley, Fred Taylor, M. P. Higgins, James Dodge, and F. L. Emory took part. The papers entitled "A Silent Chain Gear," by Mr. J. O. Nixon; "The Bursting of Small Cast-Iron Fly-Wheels," by Prof. C. H. Benjamin, that had been deferred from the morning session, were discussed by Messrs. Emerson, Rockwood, Frith, Cary, Soule, and Reist.

Three of the Society's professional committees which had been considering the questions referred to them presented reports at this session. The first was a report of progress from the Committee on Standard Methods for Conducting and Reporting Steam Engine Trials, which was presented by Professor Jacobus, and received commendatory comment from Messrs. Rockwood, Kent, Goss, and Cary. This committee was continued, to present its final report at a later meeting.

The second committee was that on Standardization of Direct Connected Engines and Dynamos, which was presented by Mr. A. L. Rohrer, member of the Committee.

The third committee report was that on the Standard Proportions for Pipe Unions, which was presented at a later session by Mr. George M. Bond. Mr. Kent inquired concerning the object of taking a copyright upon the report, and it was explained that the purpose of this idea was to secure the recognition of the standard character of fittings bearing the initial "S." By having this designation copyrighted, unauthorized use of the mark would be prevented. The purpose was the same as that in connection with the official gauge for thicknesses in decimals, so that a license may be issued for a nominal sum, while control was kept by the Society as owners of the copyright. In connection with the two latter reports, the Society took the usual action, which has become its precedent in the case of such committee reports. It was resolved that the reports be accepted, and published in the *Transactions*, but that no official action looking to a procedure similar to adoption should be inferred from the action of the Society. At a later session the following resolutions in connection with these reports were presented, and passed:

Resolved, That the thanks of the Society are due, and are hereby tendered, to Messrs. Stanwood, Ball, Forbes, McFarland, and Rohrer, members of the Com-

mittee on Standardization of Engines and Dynamos, who have just completed their labors and presented a full report.

Resolved, That the thanks of the Society are due, and are hereby tendered, to Messrs. Vogt, Baldwin, Bond, Flagg, and Herr, members of the Committee on Standardization of Proportions for Pipe Unions, who have just completed their labors and presented a full report.

Resolved, That the Secretary be instructed to forward a copy of this vote to each member of the above named Committees.

Friday Morning. Closing Session. December 5th.

The papers of the morning were as follows:

"A New Valve Gear for Gas, Steam, and Air Engines," by E. W. Naylor; "The Potter Mesh Separator," by F. A. Scheffler; "Working Loads for Manila Ropes," by C. W. Hunt; "The Heat Engine Problem," by C. H. Lucke; "Experiments on Spiral Springs," by C. H. Benjamin; "Water-Power Development at Hannawa Falls," by W. C. Johnson; "The Porro Prism," by W. R. Warner; "Effect of Clearance on the Economy of a Small Engine," by Albert Kingsbury. The participants in discussion were Messrs. Suplee, Barr, J. J. de Kinder, A. C. Wood, Ashworth, Frith, Cary, Henning, Fowler, Kent, Emory, Brashear, Dodge, Jacobus, Goss, J. E. Johnson, and Longwell.

At the close of the regular docket Mr. Victorin presented in the form of a Topical Discussion the results of certain experiments made for him at the Watertown Arsenal, with respect to the elastic deformation of large surfaces under heavy loads. The lateness of the hour prevented any formal discussion upon the facts presented.

At the close of the discussion on the professional papers, on motion of Mr. G. C. Henning, the Society tendered a vote of thanks to Mr. H. H. Cammann, Comptroller of the Trinity Church Corporation, for his share in the beautiful service which he had procured for the Society in connection with the unveiling ceremonies at Trinity Church on Thursday afternoon. The President, before putting the motion to adjourn, took occasion to thank the Society for the honor which it had conferred upon him in making him President, and turned over the office of the presidency to the new incumbent, Mr. Edwin Reynolds.

After a brief reply from Mr. Reynolds, the meeting adjourned.

The afternoon of Wednesday was left without assignment, for the members to make use of the time as might suit their individual convenience.

The evening of Wednesday was set aside for the holding of the usual reception, which has become a regular feature of the annual meeting. The retiring President with his wife and the incoming President acted as a reception committee, and the members and guests were introduced to them on their entry into the rooms. The latter part of the evening was devoted to music and dancing. About 616 were present. It was found desirable to inaugurate the custom of asking all attendants at the reception to present cards of admission at the door.

On the afternoon of Thursday an event of particular interest took place in the lower part of the city. At two o'clock, by the courtesy of Mr. Peter F. Meyer, the Board Room of the Real Estate Exchange, No. 111 Broadway, was put at the service of the Society, for the delivery of the memorial addresses by Rear-Admiral George W. Melville and Prof. R. H. Thurston in commemoration of the achievements of Robert Fulton. Admission to the rooms was from the Trinity Place entrance, immediately adjoining Trinity Churchyard. The exercises were made specially interesting by the presence of Chief Engineer Charles H. Haswell, who was the first Chief Engineer of the United States Navy. After the addresses the meeting adjourned to the edifice of Trinity Church, wherein was held a full choral service, after the ritual of the Episcopal Church, with an address by the Rev. Robert Fulton Crary, of Poughkeepsie, N. Y., who is a grandson of Robert Fulton.

At the conclusion of the service the Society and its invited guests filed in procession past the monument to Robert Fulton, which had just been completed and erected in Trinity Churchyard. The addresses of this afternoon and photographs of the monument will constitute a special paper, to be presented as part of the *Transactions* of the Society.

No. 915.*

THE EARLY HISTORY OF OPEN-HEARTH STEEL MANUFACTURE IN THE UNITED STATES.

BY S. T. WELLMAN, CLEVELAND, OHIO.

PRESIDENT'S ADDRESS, 1901.

In choosing a subject on which to address you to-night, it occurred to me that I could not do better than take as a topic "The Early History of Open-hearth Steel Manufacture in the United States." I am led to do this, first, because I was directly and intimately connected with several of the works where the manufacture was first carried on, and hence can speak from personal knowledge; and, second, from the fact that very little has been heretofore written in regard to this pioneer work. It has seemed to me that you might possibly be interested in a short statement of the facts in regard to the starting of this branch of the steel industry in America, which, beginning in so small a way, is now fast becoming the most important line of the business.

Before taking up the subject in detail, a few facts as to the inception of the process in Europe may not be out of place. The idea of making steel by an admixture of cast and wrought iron melted together on the open hearth in a reverberatory furnace was first proposed by the French philosopher Réaumur in 1722. We have records of this process being tried several times by different persons during the eighteenth, and the first half of the nineteenth century. In France, a commission appointed by the French Government, under Louis Napoleon, spent a large amount of money on experiments in trying to melt steel on the open hearth of a reverberatory furnace. They succeeded in reaching the necessary temperature, but all of these early experiments failed to be a commercial success, on account of the destructive

* Presented at the New York meeting (December, 1901) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

action of the heat on the lining of the furnace. The heat was obtained only by intensely rapid combustion of coal or coke, which created such a cutting action on the brickwork that the furnace burned out in a very short time, and the quantity of fuel used was so enormous that the process was always a failure from a commercial standpoint.

The melting of steel in regenerative open-hearth furnaces was first proposed by C. W. Siemens in 1861. It was tried in a very small way, by one or two of his licensees, but we have no record of its having been put into successful use. Messrs. Pierre & Emil Martin at the Sireuil Works, near Paris, were the first to carry out the process on a commercial scale, they having built a furnace at their works in 1864, under a license from Siemens.

Speaking of this furnace, C. W. Siemens, in a paper read before the Chemical Society, May 7, 1868, said: "It was chiefly intended for a heating furnace, but was so constructed of Dinas silica brick and of such form, that it could be used as a melting furnace." Messrs. Martins' experiments with this furnace were quite successful, and soon became known all over the metallurgical world, creating a great deal of interest.

Among the many iron masters who became interested in the process was Mr. Abram S. Hewitt, who purchased for his firm (Messrs. Cooper, Hewitt & Co., of Trenton, N. J.) the rights in the patents for America. Mr. Fred J. Slade, their engineer, was sent over to France to study the process. When he returned home, Messrs. Cooper, Hewitt & Co. immediately started to erect a small furnace at their works to try the process. This furnace, of only four or five tons' capacity, was put in operation during the fall of 1868, the gas producers being of the regular Siemens type, and built from drawings furnished by Messrs. Siemens' agents in America. I was, at the time, assisting Messrs. Siemens' engineer, Mr. J. T. Potts, who had been sent to this country by C. W. Siemens to have charge of the erection and starting of the first regenerative furnace which was built in this country. This furnace was for the melting of crucible steel, and was built at the works of Messrs. Anderson, Cook & Co., of Pittsburg, Pa. I was sent by Mr. Potts to Trenton, to assist Mr. Slade in the starting of their gas producers, with which they were having some trouble, thus having good opportunity to see the first efforts to make open-hearth steel, and I have a very vivid recollection of some of these experiments.

Mr. Slade was the only man connected with the works who had ever seen a heat of open-hearth steel melted, and as he was not a practical steel man, he probably overlooked some of the important points while watching the manufacture in France. At any rate, everything bad that could happen in the manufacture of open-hearth steel seemed to fall to their lot. The best man among the workmen was the melter, who had been an old puddler, or heater, but of course he was unaccustomed to such high temperatures as were necessary to melt mild steel. The first trouble encountered was with the making of good gas. This arose from a too literal interpretation of the printed instructions for running the producers, which had been sent them by Messrs. Siemens' agents.

When I took charge of the producers, I found they were full to the very top, the coal being some six or seven feet deep; so thick a fire that about all the heat in the bottom of the producers could do, was to drive out the moisture from the upper layers. Water and thin tar were running out of the joints through the whole length of the gas flue, or cooling tube, which was of wrought-iron plates, placed above ground. We ran the producers for two days without charging any coal. After about twenty-four hours' work, the producers began to do good service, and we had no further trouble with them. The only difficulty was to get men to attend faithfully to the making of the gas, a very disagreeable job, and one that demands constant watchfulness in order to get the best results.

Before trying to describe the melting of the first heats, a word or two about the furnaces, and the method of casting. The furnace was a Siemens' regenerative furnace, I suppose copied from one in use at Messrs. Martins' works, near Paris. It had a very flat shallow bottom, but there did not seem to be much trouble in getting it up to a fair steel-melting heat. The regenerators seemed to be of ample size, and the furnace fairly well designed for its work, except as to the shape and depth of the bottom, which was entirely too shallow for the quantity of steel it had to hold. On the casting side of the furnace, in front of the tapping hole, was fastened a kind of fore-hearth, called by the workmen, from its shape, "a shoe." In the bottom of this, at the outer end, was placed a firebrick nozzle, in which was fitted a fire-clay stopper, by which the flow was regulated. Running parallel with the front of the furnace was a narrow-

gauge railroad, on which were placed the cars for the ingot moulds, which were arranged for group casting. These cars were moved by a chain windlass placed at one end of the track. In all the heats which I saw made, Franklinite pig iron was used for the bath, and the balance of the heat made up from puddled bars and scrap steel. This mixture should have made good steel, but unfortunately they had no ferro-manganese, none being made at that time in this country, and but little, if any, in Europe.

For recarbonization, they used a small quantity of Franklinite pig; according to my recollection, not more than 1 to $1\frac{1}{2}$ per cent. of the weight of the charge. As the Franklinite contained only about 10 per cent. of manganese, this gave them a steel very low in that element, with at the most not more than $\frac{15}{100}$ of 1 per cent., and often only a mere trace. The result was, a steel which was difficult to roll, except at a high temperature. It would stand a welding heat, and a dull red heat, but was yellow short, and any attempt to hammer or roll it at that temperature resulted in the steel going to pieces. If the furnace bottom had been made of magnesite or other basic material, the amount of manganese would have been quite sufficient to have made the steel workable at all temperatures.

In the first heat at Trenton, when the melter thought, from the small test ingots taken, that the metal was ready to cast, a small quantity of Spiegeleisen was added, and when this was melted, a bent bar was driven through the sand wall between the "shoe" and the furnace. When this bar was withdrawn, it allowed the steel to run out and fill the shoe to the level of the steel in the furnace. The stopper being opened, the steel ran out through the nozzle into the moulds. When the first group was filled, the stopper was closed, and the car was moved along until the next group came under the nozzle. In this manner, about one-half of the moulds were filled when the nozzle in the bottom of the shoe began to close up by the metal chilling. It soon closed up entirely, and the car was then moved along until the next group of moulds was in place under the nozzle, when the whole nozzle was lifted out of its place, and the steel then came with a rush for a short time. This operation was repeated until all the steel that was liquid had drained out of the furnace. Only a small proportion made ingots which could be rolled; the larger portion was scrap.

The great difficulty in these pioneer days of steel making was to teach the melters to maintain the steel at the proper temperature. The margin between the proper casting temperature of the steel and the melting-point of the furnace itself was very narrow, much more so than to-day, as at that time no silica brick was available, and we were obliged to use clay firebrick for the roof and sides of the furnace. Shortly after the heat which I have mentioned, I saw an attempt made to cast a charge which had chilled in the nozzle so that it could not be started again. By the time the shoe could be taken off, the steel had chilled solid, clear back into the furnace, which was then shut down half full of steel. The next day the furnace was started up again. A quantity of pig iron was added and the steel finally all melted, but it was so slow in coming to a steel-melting heat that the carbon was reduced, and several more additions of pig iron had to be made, until finally the furnace was overfilled, making it all the more difficult to get the proper temperature. It was finally tapped, but it was so cold that it chilled in the nozzle and the forehearth, so that when the latter was taken off the steel ran down over the moulds, cars, and tracks, welding the whole together, and making a mess that I was afterwards told took two weeks to clean up so that the furnace could again be started. These are only examples of the difficulties and rough experiences which were encountered in these initial trials, and it was no wonder that poor Mr. Slade was discouraged.

As is very often the case, this experiment was not very profitable to the pioneers, Messrs. Cooper, Hewitt & Co. The furnace was operated at intervals for a year or two, but was finally abandoned, and the manufacture stopped, as it was not a commercial success, though those who saw the experiments were able to profit by them and avoid many of the difficulties encountered in them.

The second works to make open-hearth steel in America, and first to make a commercial success of the manufacture, was The Bay State Iron Works, of South Boston, under the superintendence of Mr. Ralph Crooker. Mr. Crooker was an iron master of the old school, and at the time of my association with him had been connected with the management of iron works, in one capacity or another, for over fifty years.

The Bay State Iron Company had been manufacturers of iron rails for many years, but about this time the advent of steel rails

had induced them to experiment in the manufacture of steel-headed rails. Their first experiment was with puddled steel, which was used in the head of the rail, in place of the hard wrought-iron which had generally been used for that purpose. As this did not prove to be a success, Bessemer steel ingots were brought from Troy and rolled into bars, which were used in the pile to form the head of the rail; this also was unsuccessful. Bessemer steel as then made was found to be very irregular in quality, and sometimes impossible to weld. At this stage Mr. Crooker's attention was called to the experiments which were being made in the manufacture of open-hearth steel at Trenton. He visited the works, and after watching the process for some time, became convinced that with a properly constructed furnace, and the use of ferro-manganese, a good weldable steel could be made. He tried to make some arrangements with Messrs. Siemens' agents to supply him with plans for a furnace such as he wanted; but failing in this, he sent for me, I having left Messrs. Siemens' employ several months before this. I soon came to terms with him, and in a few weeks we had the plans well in hand, and started the construction of the proposed works.

The erection of these, started in 1869, was completed in a few months, and they were put in operation early in 1870. The plant consisted of one furnace of a capacity of five tons, two sections of which are shown in Fig. 1; the necessary gas producers were also built, as well as a coal-fired preheating furnace, and several anthracite crucible steel-melting furnaces for the manufacture of ferro-manganese. The melting furnace was a very powerful one for its size, sharp and quick in its working. The arrangement of ports as shown in the drawing, with several small ports, side by side, and thin division walls between them, gave a very good mixture of gas and air. These thin walls were only 4½ inches thick, and often burned through, which necessitated very frequent repairs; otherwise the furnace was all right, and many furnaces have been built since that did not work as well as this one. The bath was made much deeper than the one at Trenton in proportion to its size; the metal was cast through a forehearth in much the same manner as at Trenton, but the ingot moulds were carried on a large turn-table resting on conical rollers, which was turned by a steam engine through the medium of bevel gearing. This made a very good arrangement,

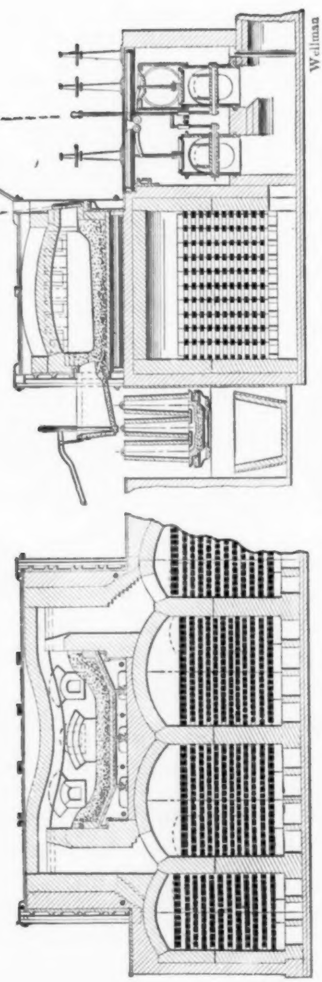


Fig. 1.—Five-ton Siemens Open-hearth Melting Furnace at the Bay State Iron Works. 1869.

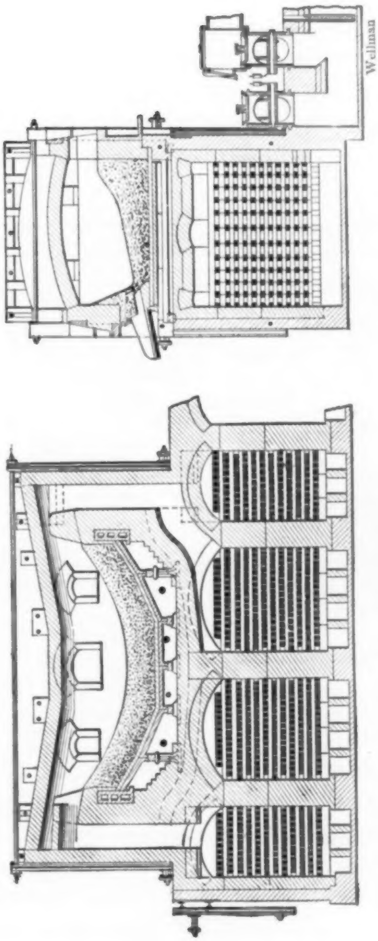


FIG. 2.—SEVEN-TON OPEN-HEARTH FURNACE, OTIS STEEL CO., LTD. 1873.

and as it was well designed and built, it gave no trouble in operation.

The melter was a skilled heater who had been in the employ of the Bay State Company for many years. He was a man of most excellent judgment, ambitious, faithful, and conscientious in his work. Having had the advantage of spending a few weeks at Trenton, watching that furnace in operation, he was able to start up the Bay State furnace without much trouble, and soon became a first-class melter. The Bay State plant started off with one very great advantage over that at Trenton,

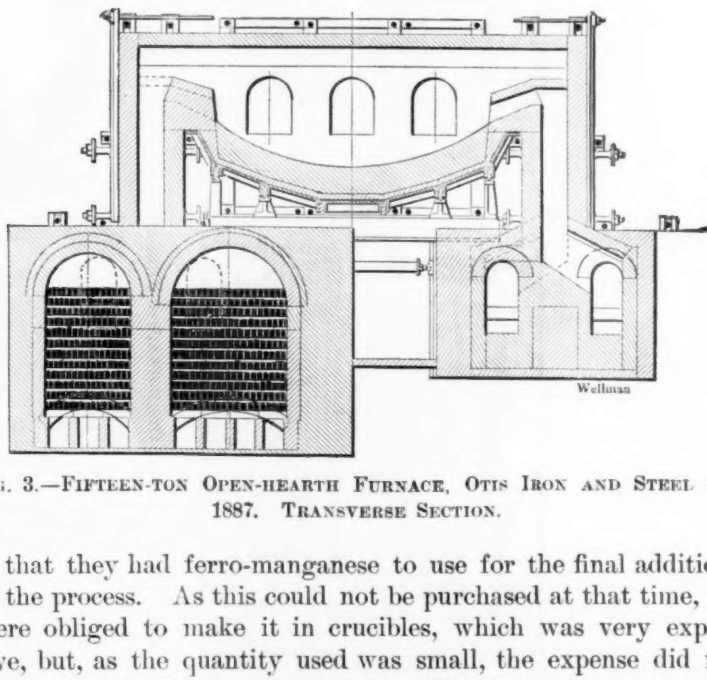


FIG. 3.—FIFTEEN-TON OPEN-HEARTH FURNACE, OTIS IRON AND STEEL CO. 1887. TRANSVERSE SECTION.

in that they had ferro-manganese to use for the final additions in the process. As this could not be purchased at that time, we were obliged to make it in crucibles, which was very expensive, but, as the quantity used was small, the expense did not amount to much per ton of steel. The ferro-manganese was made by reducing black oxide of manganese in crucibles, with charcoal and lime at a very high temperature. When nearly, or quite melted, Spiegeleisen or Franklinite pig iron containing about 10 per cent. of manganese, was added to the melted manganese in the crucible, and when the whole was thoroughly melted, it was poured into flat moulds. Most of this ferro-manganese contained 35 to 40 per cent. of manganese, not very rich when compared with the 80 per cent. product which is turned

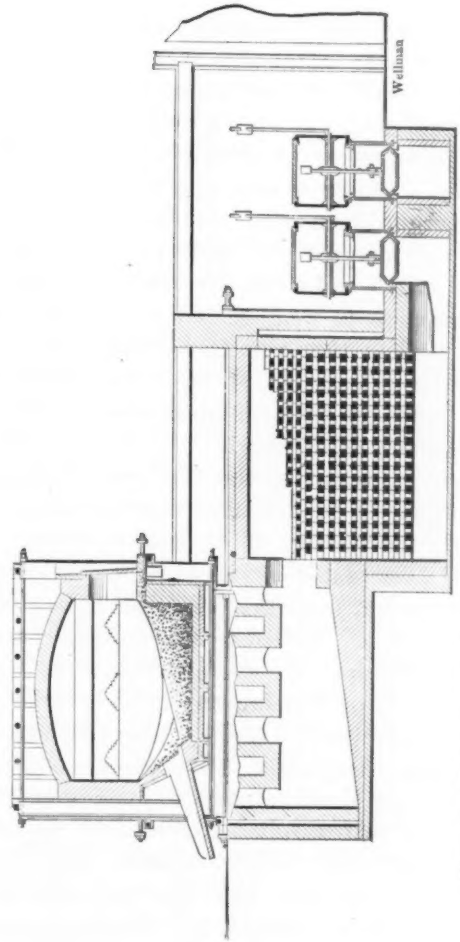


FIG. 4.—FIFTEEN-TON OPEN-HEARTH FURNACE. 1887. LONGITUDINAL SECTION.

out of the blast furnaces in these days; but it answered the purpose, and by its use we were able to make steel of from .10 to .15 carbon that was perfectly malleable at all temperatures. This was a very important advance over the first experiments at Trenton. The first steel was made from a mixture of puddled bar made in the Bay State Company's furnaces, with some scrap steel, melted in a bath of English West Cumberland hematite pig iron, and was rolled into bars about 7 inches wide by 2 inches thick. This bar of steel was used for the top of the rail pile, and formed about one-quarter of its weight, the remainder of the pile being made of old iron rails, the weld being apparently as sound as if it were iron on iron. Quite a large quantity of rails was made in this manner and put into use; but the day of "weldless steel rails" had come, and while the steel-headed rails gave better results as to wear than those of iron, they did not begin to do as well in that respect as those made of solid steel, and besides were inferior in strength and stiffness, qualities which had as much to do with good-wearing results as mere difference in hardness of the head.

It soon became apparent to the Bay State Company that the steel-headed rail was a failure, and that they must look to some other outlet for the product of their steel plant. They were large makers of iron plates as well as rails. Their flange plates had a good reputation, but were costly to make, being puddled from charcoal pig iron. Added to this expense was the tremendous loss from blistering, the average being from 40 to 50 per cent., that amount of plate being cut up and worked over again, making a very serious item of cost. These troubles, and the fact that some very good flange and fire-box steel had been made in Pittsburg in crucibles, induced them to experiment in the manufacture of soft-steel plates, rolled from ingots made in the open-hearth furnace. The first were made from their own bars, puddled from charcoal iron; but this was not satisfactory, as the iron contained too much phosphorus. After quite an amount of experimenting, a small quantity of steel was produced from blooms made in the Lake Champlain district, direct from the ore in the old-fashioned Catalan forge. The result was most satisfactory; a beautifully soft, ductile steel was produced that was perfectly malleable, hot or cold; plates rolled from it never showed a blister, and seldom defects of any kind, and most satisfactory of all was the fact that it could be produced much

cheaper than the best iron flange plates. A great many samples of this plate were sent around to different customers, and the company very soon secured a large trade in boiler and fire-box plates, which they were able to hold for several years. Only one furnace was ever built at the Bay State Works, but this furnace was run day and night for several years in the manufacture of the highest class of ingots for boiler and fire-box plates, and as the price was very high, this small steel furnace earned a great deal of money for the company.

The next firm to build an open-hearth furnace was the Nashua Iron Company, at Nashua, N. H. It was a 5-ton furnace, built under license from Messrs. Siemens. After I had finished and started the Bay State Company's plant, I was employed by the Nashua Company (of which my father, Mr. S. K. Wellman, had been for many years superintendent) to build and take charge of the new steel department at the Nashua works, consisting of the open-hearth furnace plant, and a plate and bar mill. The building was started in 1871, and completed and put in operation the following year. There were some radical changes made in the plant from that of the Bay State Company; no preheating furnaces were used, blooms, when they were used, being heated in a pair of chambers on the charging side of the furnace, and pushed off into the bath when they had reached the proper temperature. English hematite pig iron was used for the bath, to which were added charcoal blooms from the Lake Champlain district, similar to those used by the Bay State Company when making the best quality of steel; a cheaper grade was made from steel and iron scrap, and pig iron. Ferro-manganese was melted in a regenerative crucible steel melting furnace from a mixture much the same as that used at the Bay State Works. The steel was tapped from the furnace into a ladle, mounted on a car running on rails, these being placed on each side of a deep casting pit, in which the ingot moulds were placed. The pit ran at right angles to the furnace, the ladle car being hauled by a chain and windlass worked by hand, thus making a cheap and effective casting arrangement. For a stationary furnace, it had a great advantage over the use of a shoe, similar to those used on the Bay State and Trenton furnaces, as no matter how cold the steel was, it was always hot enough so that it ran "clean" out of the furnace. While some of it might chill in the ladle, the furnace was not interfered with at all, and we were able to get

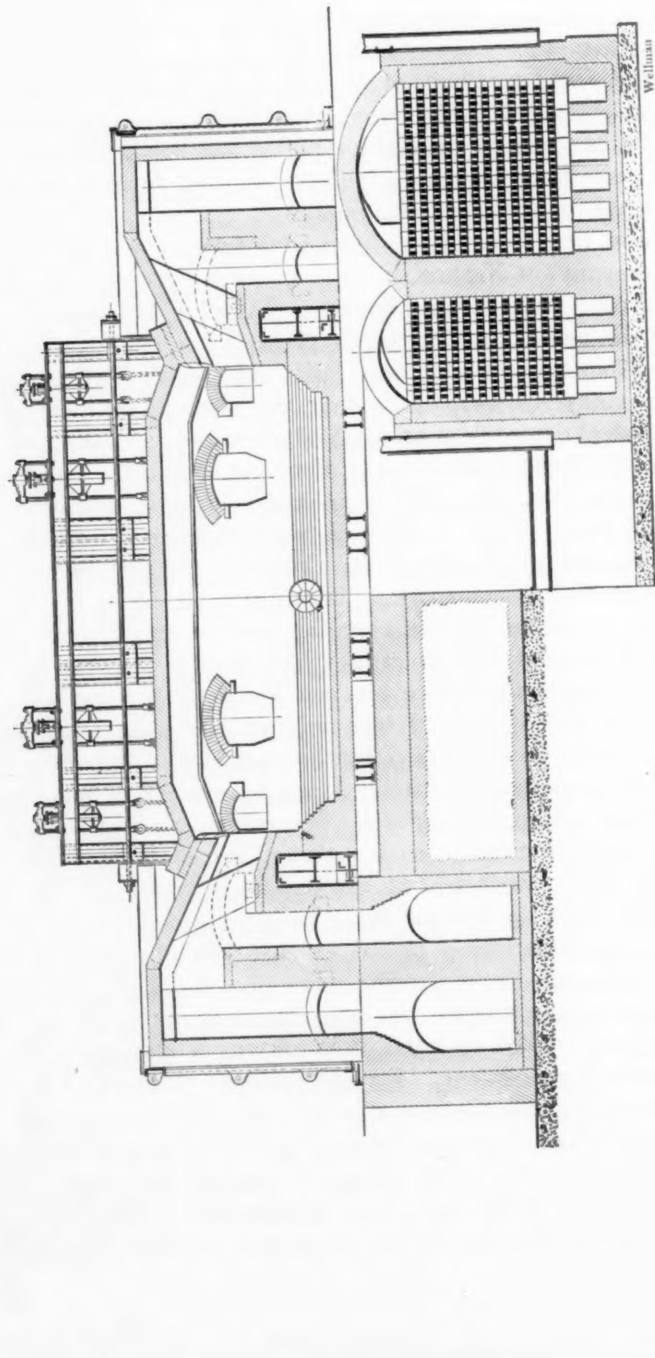


FIG. 5.—FIFTY-TON OPEN-HEARTH FURNACE, DUQUESNE STEEL CO. 1900. TRANSVERSE SECTION.

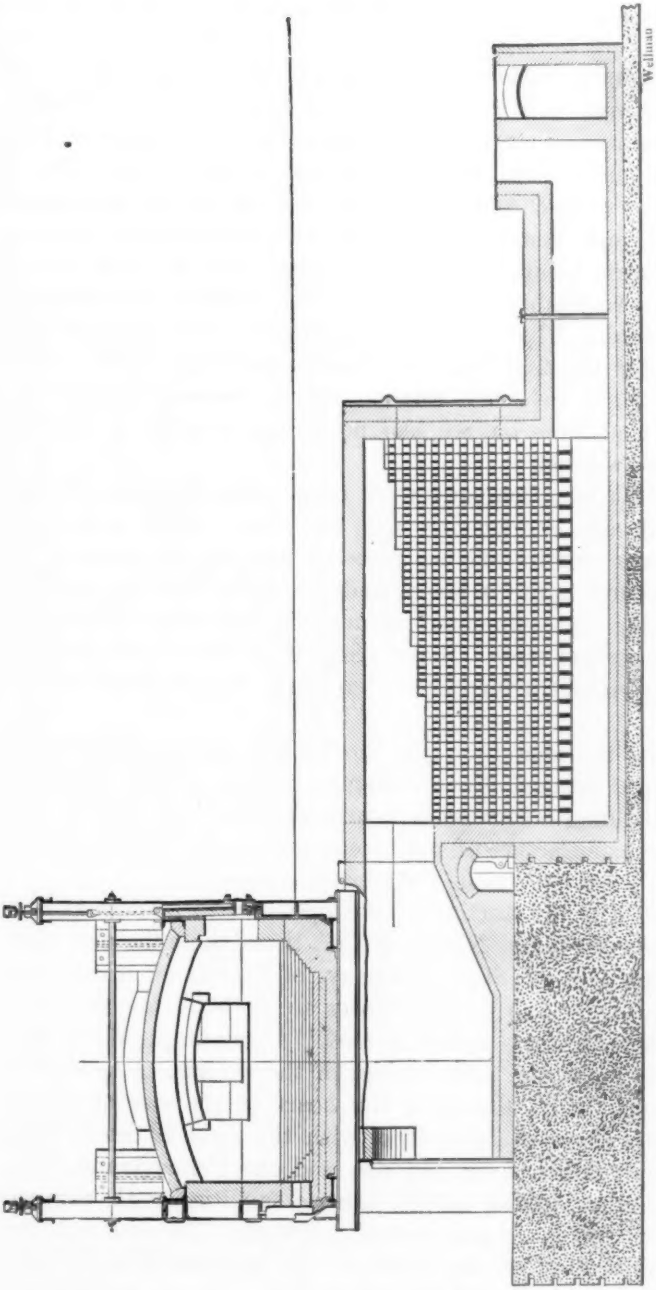


FIG. 6.—FIFTY-TON FURNACE. LONGITUDINAL SECTION.

out the next heat without interference from steel left in the furnace. Such a casting arrangement as that used at Nashua would not answer in these days of 50-ton furnaces, but it answered the purpose very well at that time. I have a vivid recollection of the first week's work after we started up the furnace at Nashua; we ran single turn, and were trying to make steel from cheap stock for some common forgings, but not an ingot in the whole week's work would forge at any temperature, and you may be sure I went home, that Saturday night, sick in mind and body. I do not remember the sermon on that Sunday; but before Monday morning I had found out the trouble with my steel making, and after the first heat on Monday morning, which proved to be all right in every respect, things looked brighter to me. From that time on, we had no serious trouble in making any steel we wanted.

The Nashua Company were large manufacturers of forgings for railroads and marine uses, and much of the steel made by them was used to take the place of iron for this purpose. They also secured quite a large trade in boiler and fire-box plates, and later on commenced to manufacture steel for locomotive and car-wheel tires. Some years later this 5-ton furnace was torn down and a furnace of ten tons' capacity was built in its place.

About the same time that the Nashua Company were building their first furnace, Messrs. Singer, Nimick & Co., of Pittsburg, were building a furnace of nearly the same size, which was used for the manufacture of mild steel, principally boiler and fire-box plates, previously made from crucible steel.

Following the starting of the open-hearth furnace at Nashua, and that of Singer, Nimick & Co., there came the new works of the Otis Iron & Steel Company, of Cleveland, which was the first plant in the United States to be built for the exclusive manufacture of open-hearth steel. I was engaged by the company to build and take charge of the works. A splendid location was found, almost in the heart of the city of Cleveland, near the shore of Lake Erie, with the Lake Shore & Michigan Southern Railroad on one side and the Pennsylvania Railroad on the other, giving ample railroad facilities, with competition both on incoming and outgoing freight. Ground was broken for the erection of the works in the summer of 1873, but they were not finished until the fall of 1874. At my suggestion, Mr.

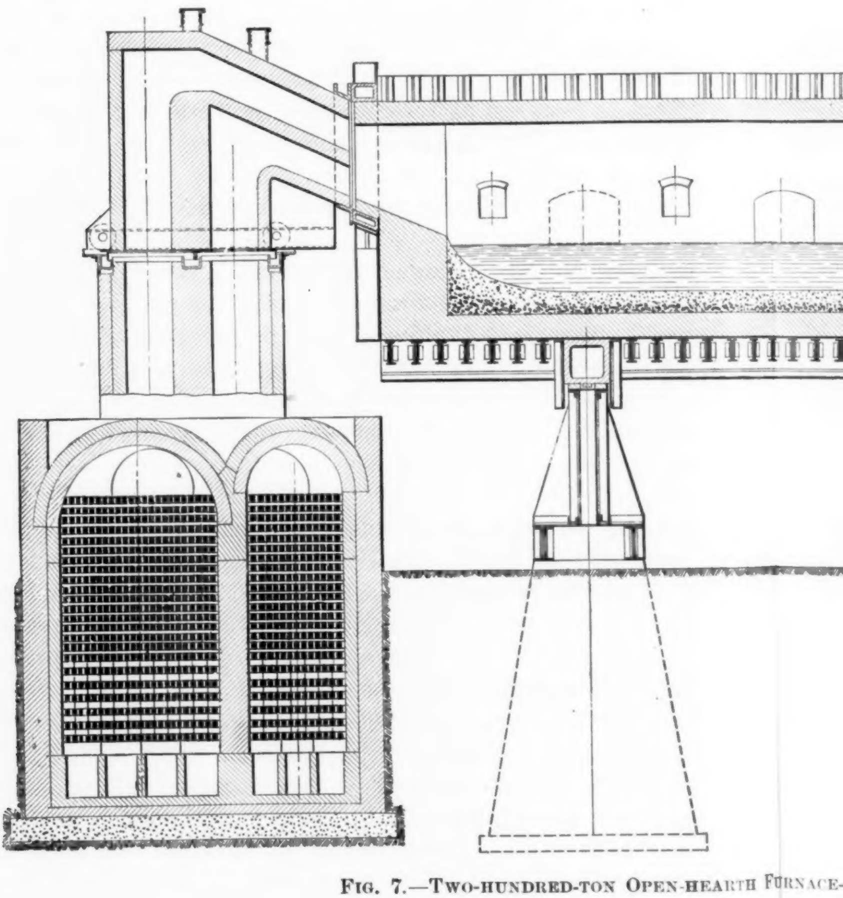
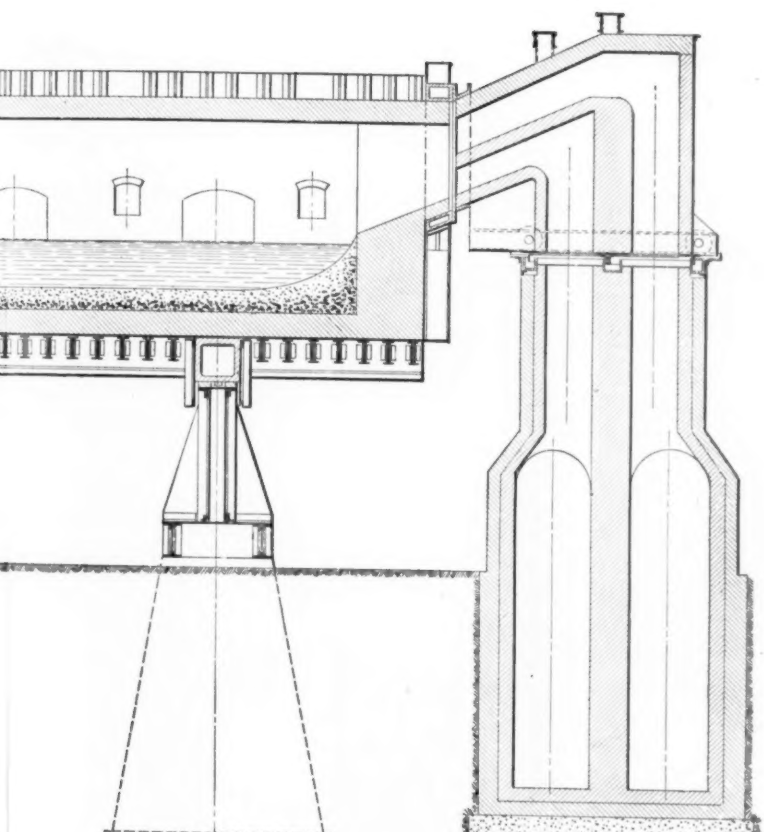


FIG. 7.—TWO-HUNDRED-TON OPEN-HEARTH FURNACE-



URNACE—PROPOSED. 1901. TRANSVERSE SECTION.

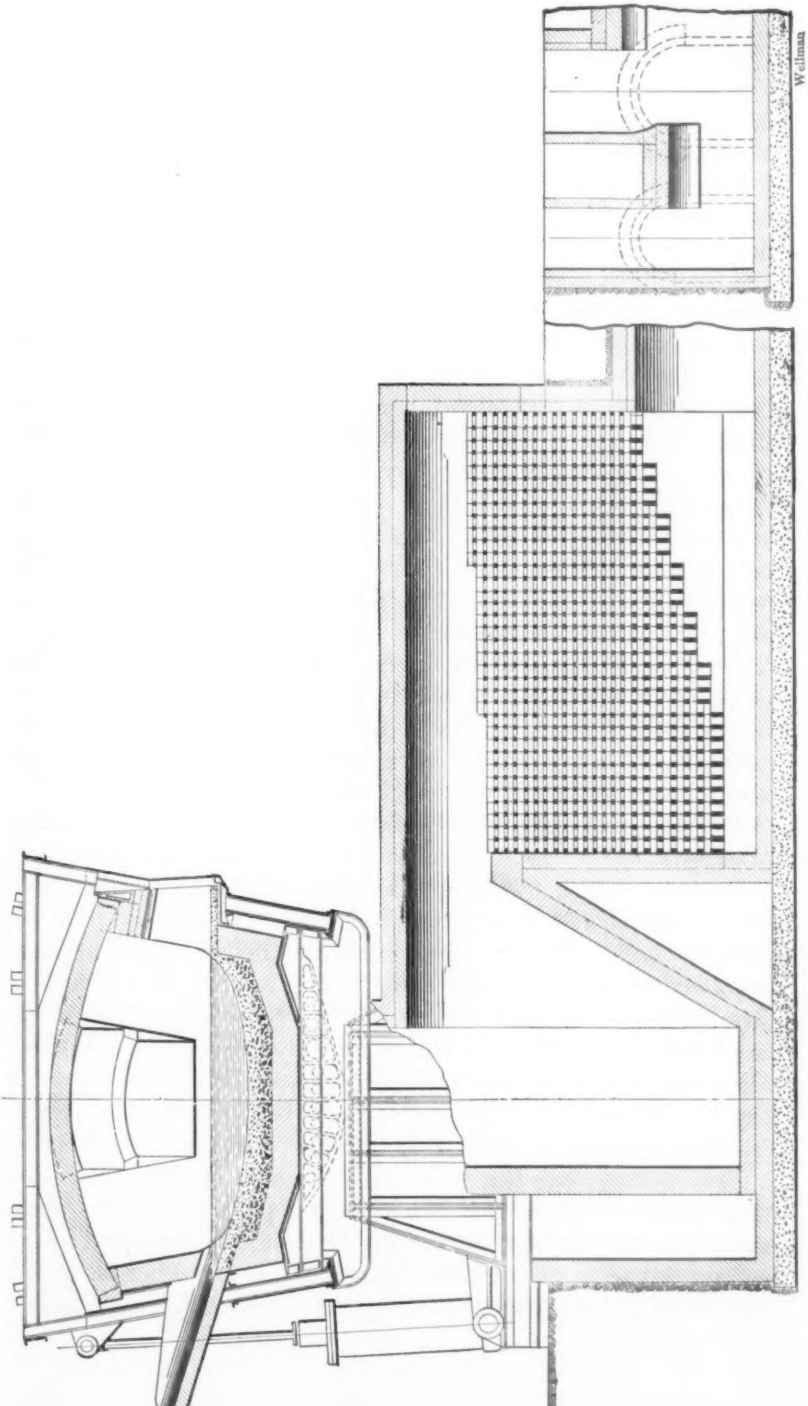


FIG. 8.—TWO-HUNDRED-TON FURNACE. LONGITUDINAL SECTION.

Alexander L. Holley was appointed consulting engineer, and served the company for several years in that capacity.

I had seen Mr. Holley but once before he came to Cleveland on the occasion of his first visit as consulting engineer. That was seven years before, when he was in charge of the works at Troy, and I, wanting to learn the steel business, had asked him to give me a position there. He told me that he had no vacancies at that time. On his visit to Cleveland I recalled this circumstance to him, and laughingly said, "As long as you would not give me a position, I have at last succeeded in getting you one." This was the commencement of one of the most pleasant friendships of my life, which lasted until Mr. Holley's death.

Many plans for the general arrangement of the works were considered between us, and the one finally adopted, with some minor alterations, was one suggested by him. The steel-melting plant, as originally built, consisted of two 7-ton furnaces (Fig. 2) with a regenerative, preliminary furnace for preheating the blooms, before adding them to the bath, and a regenerative-crucible, ferro-manganese furnace. The most radical improvement over old practice was the raising of the charging platform about 10 feet above the general level, the material to be melted being raised by hydraulic elevators, an arrangement which made the furnaces very accessible for repairs, and also gave the great advantage of being able to use a shallow casting pit. This plan is still followed by the latest and best works in this country.

The steel was tapped into a ladle, as at Nashua; only, instead of supporting the ladle on a car, it was carried on the arms of a jib crane, which was simply a swing, without any lift. This made a simple and cheap casting arrangement, and one that was perfectly safe. The one crane stood on the centre line between the two furnaces, and the ladle swung around to the tapping spout of each; as there was no lifting of the ladle when it was filled with metal, there could be no break-downs or upsetting. Since the ladle could not be lifted, we were obliged to bring the top of the moulds or groups to very nearly the same height, which in the case of moulds of different lengths was sometimes a disadvantage, but the safety of the whole arrangement more than compensated for this. A swinging platform for the workmen to stand on when tapping the furnace was supported at one end on the mast of the ladle crane, and at the other on wheels which ran on the plates covering the walls of the casting pit.

The furnaces were very simple in construction, and much like the one at Nashua, excepting that the heating chambers on the front of the melting furnace had been dispensed with, and a preliminary furnace used, as at the Bay State works; one furnace with doors on each side served for the two melting furnaces. The first heat of steel was made in October, 1874, of charcoal blooms from the Lake Champlain district, melted in a bath of Lake Superior charcoal pig iron. The steel was naturally of very high quality, and was made into plates for fire boxes.

The starting of the works was attended with the usual mishaps which always attend the launching of new enterprises, especially in the iron business. The first thing to happen before any metal had been charged into the furnaces, was a terrific gas explosion, which cracked the main gas flues, loosened up the gas and air valves, smashed man-hole plates and escape valves, and disarranged things generally. After our furnaces were started, they were occasionally fused down by careless melters, and the steel did not always prove to be what we expected; but a careful system of inspecting prevented these mistakes from getting to our customers, and after a few months' schooling of this kind things began to work smoothly, and we had comparatively little trouble in making what we wanted. Of course, we had to educate all of our skilled men; having no works from which to hire them, we had no other way. Our head melter, who originally came from New England during the construction of the works, was by trade a bricklayer—a bright and observing fellow, who was ambitious to learn the steel-melting business. I sent him to Nashua and Boston some two or three months before we started up the works, to learn what he could about the operation of the furnaces there. Of course, for a time he needed constant watching, but after a few months' work he became a very expert melter. Nearly all of our skilled men learned their trade after entering the employ of the Otis Company, and when I severed my connection with the company, after sixteen years' service, out of about 1,000 employees I was able to learn of only one skilled workman who had not learned his trade in the shops of the company.

Not only men, but all of our materials had to be tried and proven. The question of firebrick, as well as of other refractory materials, was an important and troublesome one, and a great deal of experimenting had to be gone through before the best

materials could be found. In the meantime we were building up a good reputation for the quality of our product, which was principally plates for boilers and fire boxes. "OTIS STEEL" was for many years a standard brand for that purpose in this country, and sold at the very highest price.

In 1878 two 15-ton furnaces were added to the plant. These were a great success from the very start, were regarded as of immense size, and were a radical step in advance of anything that had been built up to that time. In 1881 two more 15-ton furnaces were added, and in 1887 two more of the same size (Figs. 3 and 4). The last two were a distinct departure from anything that had been built before, in that the regenerators were under the charging platform instead of under the furnace proper. The opening into the regenerators was at the end next to the furnaces, instead of at the top, as is necessarily the case where the regenerators are underneath. This opening in the case of both gas and air regenerators was into a large slag pocket directly under the ports; since that time this type of melting furnace has been very largely used in this country, all of the late furnaces at the Homestead Steel Works, Duquesne Steel Works (Figs. 5 and 6), and the Sharon Steel Works being of almost exactly this type. The Otis Works was at one time the largest open-hearth plant in this country.

As I have said, the principal raw material used at the start for making the high quality of soft steel which was turned out at the Otis Works was charcoal blooms from the Lake Champlain district. These were used in largely increasing quantities from year to year, until the annual consumption reached as high as 12,000 to 15,000 tons, at an average cost of $45 to $60 per ton. This seems like an enormous price to pay for raw material; it was, but as the finished plates were sold at from $135 to $160 per ton, a fairly good margin was left for profit. Later on, a larger amount of puddled blooms were made from Bessemer pig iron in mechanical puddlers. Washed metal made in revolving Pernot furnaces by the Krupp-Bell process was also used.

The first basic steel produced in this country was made at the Otis Works in 1886. During a visit to Europe in 1885 I saw the process at work, and was much impressed with its possibilities. I immediately arranged to have a small cargo of Styrian magnesite sent over; and as soon as we could spare a furnace to

make the experiment, we put in a lining of calcined magnesite on top of the silica bottom, which had been melted down as low as possible. This magnesite was not fused in, as is the practice in these days, but after being mixed with tar was rammed in place while the furnace was cold, following the practice in Europe at that time, which we had seen. As soon as the bottom was made, we started up the furnace, which was operated experimentally for some four months, making a good quality of basic steel. All of it went to our regular customers in our regular work, without any fault being found. It was kept as a great secret, and no one outside of the company's works knew what we were doing. During all of this time we were extremely busy. The basic process was much slower in operation than the acid, and this made the output of the furnace so small that I was at last forced to yield to the pressure brought by the selling department for more steel, and changed the furnace back to the acid process. Some months later the basic process was started at the Pennsylvania Company's works at Harrisburg and the Carnegie works at Homestead. To-day at least three-fourths of all the open-hearth steel made in America is manufactured by the basic process, and this proportion is bound to increase. It is my opinion that there is no question about the fact that the very best qualities of all grades of open-hearth steel can be made cheaper and better by the basic process than in any other way. The basic process of steel making is so simple, both in theory and practice, that it seems strange that it was not thought out and put in practice before it was. The same principles are involved, and the same reactions go on in the puddling process which has been in use for generations. The only difference is that the temperatures are lower in the puddling furnace than in the open hearth; as a consequence the lining in the latter must be the more refractory.

Twenty-five years ago it was considered an axiom that phosphorus could not be removed from iron at a high temperature, but the invention of Snelus and Thomas demonstrated that it could be done. To-day thousands of tons of steel are being made by the basic open-hearth process from iron containing more than $\frac{50}{100}$ of 1 per cent. phosphorus, that is better in every respect than was the steel of which I have been telling you, made from costly charcoal blooms containing only $\frac{2}{100}$ to $\frac{3}{100}$ of 1 per cent. of that element.

Very soon after the Otis steel works were started open-hearth furnaces began to be erected all over the country. They were built by the Pennsylvania Steel Company, at Steelton, Pa.; Cleveland Rolling Mill works, at Newburg, near Cleveland; the Shoenberger works, at Pittsburg; and many others, among all of which the Carnegie works at Homestead were the most important. This is to-day the largest open-hearth plant in the world, consisting of 48 furnaces, of a capacity of from 40 to 50 tons each, having a total capacity of at least 1,300,000 tons per annum. The size has increased from the little 5-ton furnaces at Trenton and Boston up to those having a capacity of 50 tons, which is the average size now being built. Furnaces of this size nominally, at Ensley, Ala., have made heats yielding 74 gross tons of ingots.

Furnaces of 100 tons' capacity are being built, and designs have lately been made for a furnace which will probably be built of 200 tons' capacity (Figs. 7 and 8). These large furnaces, however, are not properly melting furnaces, as the bulk of all the iron is charged into them in a liquid state, direct from the blast furnace. They might more properly be called "converting furnaces."

The output of open-hearth steel has grown from 893 tons in 1869 to 3,402,552 tons in 1900, against 6,684,770 tons made by the Bessemer process in 1900. But few new Bessemer converters have been built in this country for several years, and it is not likely that many more will be built. The production of basic open-hearth steel in this country will soon exceed the Bessemer in tonnage. Mr. Holley used to say that "the open-hearth process will some day go to the funeral of the Bessemer." It will be many years before that will come to pass, but the day is not far distant when the great bulk of all the steel in this country, at least, will be made on the open hearth of the Siemens regenerative furnace by the basic process.

The drawings which I am able to place before you show the progress in the size of the furnaces, increasing from a 5-ton furnace at the Bay State works up to the 50-ton furnace at the Duquesne works, and the 200-ton furnace which it is proposed to build.

No. 916.*

FINAL REPORT OF COMMITTEE ON STANDARDIZATION OF ENGINES AND DYNAMOS.†

1. The Committee on Standardization of Engines and Dynamos has now completed its labors and has the pleasure to submit its final report, which it hopes will prove satisfactory to the Society.

Since our last report at Milwaukee, the Committee has continued its work on the same lines as hitherto, taking up carefully with manufacturers of engines and generators the points remaining to be standardized. We are glad to be able to repeat what we have said in previous reports, that the comments which have been received are almost without exception commendatory and show not only a willingness to adopt the Committee's recommendations, but an appreciation of the work which has been done.

2. The Committee's investigation has covered the standardization of the following points:

(1) The standard sizes of units recommended.

(2) The corresponding revolutions per minute for these units.

(3) The sizes of shafts for the two classes of centre-crank and side-crank engines.

(4) The length along the shaft required for the generator.

(5) The height of axis of shaft over top of sub-base.

(6) The width of top of sub-base.

(7) Armature fit.

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* Presented at the New York meeting (December, 1901) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*. The Preliminary Report, number 887, was presented at the Milwaukee Meeting, May, 1901, and will be found in Vol. XXII., p. 520.

† For further discussion on this topic consult *Transactions* as follows:

No. 818, vol. xx., p. 758: "Standards for Direct-Connected Generating Sets." J. B. Stanwood.

No. 887, vol. xxii., p. 520: "Report of Committee on Standardization of Engines and Dynamos."

(8) Overload capacity of engines and generators.
(9) Brush holders.
(10) Holding-down bolts, keys, and outboard bearings.

Size of Units.

3. Our endeavor has been to reduce the number of standard units to the fewest sizes. This will commend itself to all manufacturers as tending to reduce the great number of patterns required to be kept on hand. For reasons stated in our report to the Milwaukee meeting, the largest size embraced in our list is 200-kilowatt capacity.

In this connection our report covers the standardization of direct-current generators only.

Revolutions.

4. These standard speeds have been chosen after careful deliberation and investigation of the practice of all the engine and generator builders in the country. It will be observed that we have provided for a permissible variation of speed of *five per cent.* above or below the mean speed, which we recommend; an examination of the practice of all the engine and generator builders shows that this covers practically all the machines which may be considered as a standard make at the present time, and we have been assured by some builders whose conditions differ somewhat that if there is a general agreement upon the scheme outlined, they will be prepared to change their machinery to conform to the recommendations.

Shaft Diameters.

5. These are also the result of careful analysis of the existing practice of all manufacturers and a consideration of all the conditions affecting the diameter of the shaft. The preliminary report which we sent out to the manufacturers has elicited only a few adverse criticisms, and these, after correspondence, were withdrawn.

In order that the reason for the diameters of shafts that we have recommended shall be thoroughly understood, we may explain that (especially in shafts for side-crank engines) the

permissible deflection has determined the diameter. This, in some cases, is larger than would have been necessary for torsion and bending if deflection did not have to be considered.

As cases sometimes arise where cross-compound engines or double engines are connected to generators coming within our recommendation, and as such units require considerably larger shafts than those given in our tables, we deem it necessary to state, specifically, that our recommendations apply only to engines of usual proportions, with the generator attached at the side of, instead of between, the cranks.

Length of Generator along the Shaft.

6. When we came to investigate the question of length along the shaft (between limit lines) to be provided for the generators, we found that the practice of manufacturers required provision for two classes, which may be called "long" and "short" generators.

It would, of course, have been much better if we could have provided for but a single class, with a small allowance for variation, but there is such a marked difference in the lengths for the same power that we have deemed it best to make provision for these two classes, so that the engine builders can govern themselves accordingly. It will be noticed that the maximum difference in lengths between the two classes is six inches, which in the small sizes is reduced to five inches.

In the case where an engine is to be provided for a generator which falls into the "long" class, but which is only a little over the limit for the "short" class, or one which is considerably less than the maximum of the "short" class, the excess clearance is to be provided for on the side next to the engine; that is to say, the side away from the commutator.

We have carefully considered the fact that for these varying lengths of generator and shaft the engine builder has to provide different lengths of sub-base, and in order to reduce the expense of patterns here to a minimum, our idea is that these patterns would be made so that the end away from the commutator can be extended the necessary amount, five or six inches, to take care of the increased length of bed. Obviously, this means simply a standard pattern with a standard adjustable end for each unit.

Height of Shaft.

7. As is well known, there are two classes of generators to be provided for under this head: Those which are split vertically, and those which are split horizontally. The former have a flat base which rests directly upon the flat top of the sub-base, while the latter have feet which take the weight of the generator.

In order to arrange that the engine builders' patterns may be reduced to a minimum and still be stock patterns, which will fit every style of machine, we have chosen dimensions for height of axis of shaft above top of sub-base sufficient to allow for the vertically-split machines, and also, except as stated later, to clear the periphery of the horizontally-split machines.

As will be seen, the scheme provides for a main pattern to which patterns for the stools and seatings for both horizontally and vertically-split generators can be attached before the pattern is sent to the foundry—stools for the horizontally-split machines and rectangular seatings for the vertically-split machines. See Fig. 9.

In the case of the 150 and 200-kilowatt units, we have provided for a recess in the top of sub-base to allow the lower part of some horizontally-split generator frames to be accommodated, and so to avoid unduly raising the centre of the shaft. In the case of the vertically-split machines and those which are split horizontally and do not need this recess, the top of the sub-base will be flat and continuous.

Width of Top of Sub-Base.

8. This has been decided by careful examination of existing practice, and we believe that the figures we have recommended will cover the necessities for all sizes of generators.

Armature Fit.

9. The matter of armature fit has received very careful consideration from the Committee, and our recommendation is for what is known as a single fit.

We have obtained the opinions of manufacturers in respect to the allowance to be made for a pressed fit, and find that allowances of $\frac{1}{1000}$ inch for shafts 4 inches to 6 inches, inclu-

sive, and $\frac{2}{1000}$ inch for shafts $6\frac{1}{2}$ inches to 11 inches, inclusive, represent the best existing practice.

The armature bore is to be the *exact* size given in the table, and the allowance is to be made by the increase of diameter of engine shaft.

We believe, that in order to secure the best results, it will be necessary to work to a definite gauge; to this end we recommend that the generator builder furnish a gauge the *exact* diameter of the bore and the engine builder make the necessary allowance for the press fit, as recommended. This will avoid uncertainty as to the responsibility for the fit.

Overload Capacity of Engines and Generators.

10. All the features of our recommendation have so far had to do with the question of dimensions as affected by the mutual relations of the generator and the engine. An important point, however, which affects both the generator and the engine, is that of the overload capacity which can reasonably be expected. As is doubtless well known, generator builders are frequently called upon to provide, during short periods, for overloads of as much as 50 per cent., and, in occasional cases, of even 100 per cent.

It is evident to every engine builder that to provide an engine large enough to drive the generator under such extreme overload capacities, gives an unreasonably large engine for the rated load, and seriously interferes with the economy with which the power is produced.

Bearing in mind that our recommendations are entirely for standard practice, we are led to recommend that the standard overload rating of any direct-connected unit should not, in any case, exceed 25 per cent. of the rated capacity.

It will, of course, be understood that under these conditions of overload the economy of the unit should not be expected to be as high as when operated at the rated load. We have also been asked by some engine builders to call attention to the importance of giving the unit special attention when it is so operated.

If, under peculiar conditions, a higher overload capacity is demanded, it must be understood that this is a special case not covered by the standard machines, and provision must accordingly be made for meeting this demand.

Brush Holders.

11. We recommend what we believe is now the practice of the best generator builders, that the brush-holder rigging shall be supported upon the generator frame. This, we think, will commend itself, as it makes the electrical part of the outfit entirely self-contained.

Holding-down Bolts, Keys, and Outboard Bearings.

12. We recommend that the holding-down bolts, shaft keys for securing the generator hub to the shaft, and the outboard bearings should be furnished by the engine builders. This is in accord with almost universal practice at the present time.

Our recommendations in these particulars do not cover matters of so great importance as some others; but, if adopted, they will tend to settle certain points about which there has occasionally been dispute and considerable controversy in correspondence.

In the table will be found columns showing sizes of shaft keys which we recommend; also the number and size of holding-down bolts.

It will be noticed that we do not give any lengths for keys. We gave this matter very careful consideration, but we found that such differences of opinion existed in respect to proper length, that we believe it best to leave the determination of the length of key for adjustment by engine and generator builders in each individual case.

Sizes of keys have been taken so that standard rolled stock can be employed.

We recommend that the keys be made straight and be used as feathers. They should therefore fit accurately on the edges and not on the top. Proper allowance should be made in cutting the keyway in the armature hub, so that there will be sufficient clearance at the top of the key.

Suggestions.

13. In the course of our investigation our attention has been called to a number of points, which, from their nature, are not exactly in the same category as those on which we have made

TABLE OF SIZES, SPEEDS, AND STANDARDIZED DIMENSIONS OF DIRECT-CONNECTED GENERATING SETS.

(To accompany Diagram.)

Capacity of Unit, Kilowatts.	Revolutions per Minute.	Armature Bore.		Diameter of Engine Shaft at Armature Fit.		Space Occupied on Shaft between the Limit Lines.		*B*. Length of Extension Pieces, Inches.	*C*. Height of Axis of Shaft above Top of Base, Inches.	*R*. Inches.	*D*. Width of Top of Sub-Base, Inches.	Key (a Feather).				Holding-Down Bolts.	
		Centre Crank Engines, Inches.	Side Crank Engines, Inches.	Centre Crank Engines, Inches.	Side Crank Engines, Inches.	Long Class *A*, Inches.	Short Class *A'*, Inches.					Width, Inches.	Thickness, Inches.	Depth in Shaft at Edge, Inches.	Projection above Shaft at Edge, Inches.	Diameter, Inches.	Number.
25	310	4	$4\frac{1}{2}$	$4 + \frac{1}{1000}$	$4\frac{1}{2} + \frac{1}{1000}$	30	25	5	$23\frac{1}{2}$	Flat.	48	1	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	1	4
35	300	4	$5\frac{1}{2}$	$4 + \frac{1}{1000}$	$5\frac{1}{2} + \frac{1}{1000}$	33	28	5	25	Flat.	54	1	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	1	4
50	290	$4\frac{1}{2}$	$6\frac{1}{2}$	$4\frac{1}{2} + \frac{1}{1000}$	$6\frac{1}{2} + \frac{2}{1000}$	37	31	6	28	Flat.	60	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	1	4
75	275	$5\frac{1}{2}$	$7\frac{1}{2}$	$5\frac{1}{2} + \frac{1}{1000}$	$7\frac{1}{2} + \frac{2}{1000}$	43	37	6	31	Flat.	66	$1\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{4}$	4
100	260	6	$8\frac{1}{2}$	$6 + \frac{1}{1000}$	$8\frac{1}{2} + \frac{2}{1000}$	48	42	6	34	Flat.	72	$1\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{4}$	4
150	225	7	10	$7 + \frac{2}{1000}$	$10 + \frac{2}{1000}$	51	45	6	$37\frac{3}{4}$	$41\frac{1}{4}$	84	$1\frac{3}{4}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{5}{8}$	$1\frac{1}{4}$	4
200	200	8	11	$8 + \frac{2}{1000}$	$11 + \frac{2}{1000}$	54	48	6	$42\frac{3}{4}$	$47\frac{1}{2}$	96	2	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{5}{8}$	$1\frac{1}{2}$	4

NOTE 1.—Five per cent. variation of speed permissible above and below speeds in table.

NOTE 2.—Distance from centre of shaft to top of base of outboard bearing may be less than *C* (to suit engine builder), though not less than possible outside radius of armature.

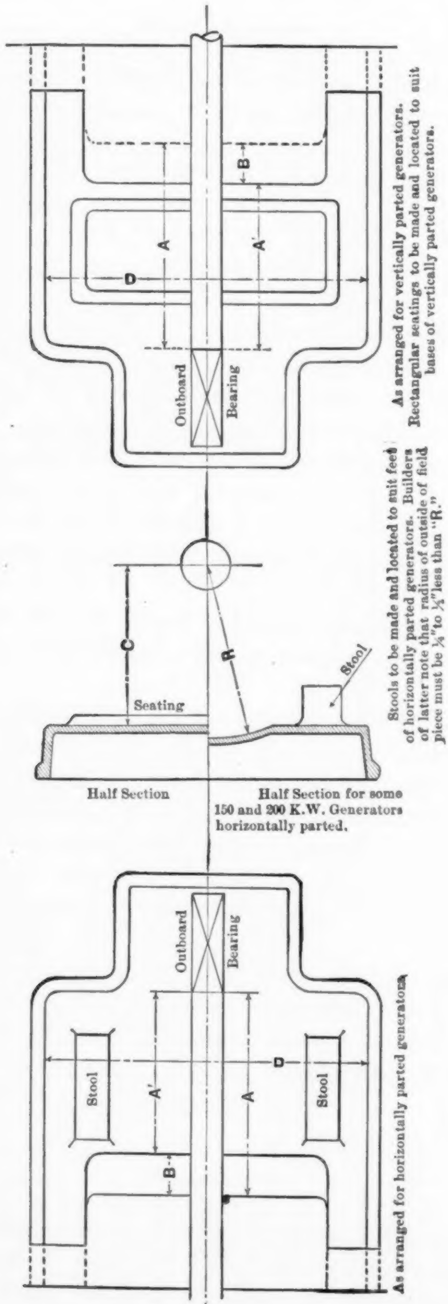
As arranged for vertically parted generators.
Rectangular seatings to be made and located to suit bases of vertically parted generators.
Outboard
Bearing
A
A'
B
D
Stools to be made and located to suit feet of horizontally parted generators. Builders of latter note that radius of outside of field piece must be ¼" to ½" less than "R."
C
R
Seating
Stool
Half Section
Half Section for some 150 and 200 K.W. Generators horizontally parted.
Outboard
Bearing
Stool
Stool
A'
A
B
D
As arranged for horizontally parted generators.

FIG. 9.

recommendations, but we consider them of such importance that we desire to offer them as suggestions for consideration by members of the Society, with a view to their adoption if considered sufficiently meritorious.

A. Pressing Armature on Shaft.—Usually the contract definitely provides by whom this is to be done, but our suggestion is that if there is no such provision in the contract, it should be understood that the engine and generator builders shall agree who is to do this work, so as to avoid any dispute when the separate portions of the unit are delivered on the premises.

B. Floor Line.—For convenience in operation and for the information of engine and generator builders, we suggest that for units up to 75 kilowatts, inclusive, the floor line should come at the bottom of the sub-base; and for units 100 kilowatts to 200 kilowatts, inclusive, the floor line should be one inch below the rough top of the sub-base.

C. Protecting Commutators from Oil.—In view of the fact that in some cases the distance between bearing and commutator is very small, it is well for engine builders to bear in mind that provision should be made to prevent oil from the bearing getting on the commutator.

D. Some generator builders have asked that the end of the shaft be drilled and tapped to facilitate, if necessary, the removal or placing of the armature on the shaft at the place of erection; we suggest that this be done.

E. In some cases, generator builders require special nuts, bolts, or fixtures for attaching generators to the shaft. Under these conditions we suggest that the generator builders should furnish all attachments to their apparatus that are not already specified in our report.

In Conclusion.

14. In concluding our labors, we desire to express our appreciation of the great interest in our work which has been shown by the engine and generator builders. They have realized that it was for their benefit, and they have helped us very materially by supplying freely the data in their possession and by their intelligent comments and criticisms of our various recommendations. We may say, indeed, that it is this spirit of helpfulness and appreciation that has encouraged us to devote the great

amount of time and labor which we have given to the solution of the problem.

We wish also to express our indebtedness to Prof. John E. Sweet, who, as president of the Engine Builders' Association and chairman of their committee on standardization, has attended all of our meetings and given us the benefit of his counsel and ripe experience.

We believe that the recommendations we submit herewith will accomplish the object for which the Committee was appointed, and will, if adopted generally by manufacturers, which we have every reason to anticipate, reduce the cost of manufacture, expedite deliveries, and remove many causes of complication and dissatisfaction.

The favorable reception accorded to our preliminary report by the Society leads us to hope that our completed work will be equally satisfactory.

JAMES B. STANWOOD,
FRANK H. BALL,
WM. D. FORBES,
WALTER M. MCFARLAND,
ALBERT L. ROHRER,

Committee on Standardization of Engines and Dynamos.

DISCUSSION.

Mr. W. A. Drysdale.—As a matter of interest, and not in any way as a criticism of this report, I give the following information as to my experience and office practice:

In the last few years we have installed over eighty plants in which direct-connected units are used, and have found that the speeds given in the report practically agree with the speeds we have used on this class of work; the only change from the table is in size of shaft, our practice being to use a greater diameter, not from the fact that the sizes given are not sufficiently large, but to eliminate all question of defects that may occur in such forgings. On overloads our practice is to require an excess above the normal rating of twenty-five per cent., and to also require an overload of fifty per cent. for a few minutes. Under this latter condition efficiency of either dynamo or engine is not considered, simply structural strength to withstand the overload. For the purpose of placing the armature on and removing it from the shaft, we designed an "Armature Jack" which has

been used successfully on all of our work. This jack was patented December 15, 1896, and a license is issued, under our contracts, without cost to the engine builder to whom the work is awarded.

Fig. 10 will give an idea of the application of this jack and its general construction.

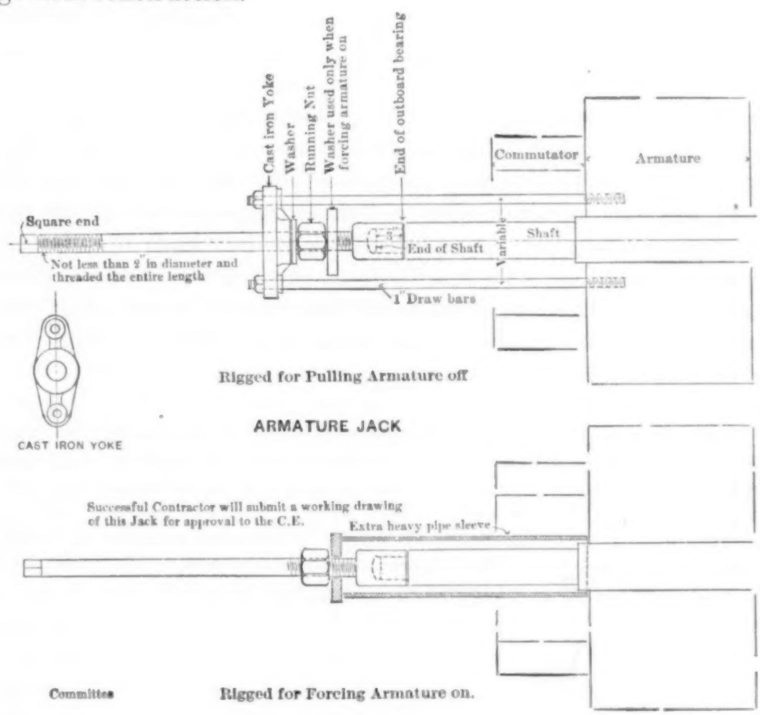

FIG. 10.

Mr. McFarland.—I only want to say that, as a member of this Committee, I endorse very heartily everything Mr. Rohrer has said about the laboring oar having been wielded by Mr. Stanwood. Let me add also that, in the work of the electric company with which I am connected, I find there is getting to be quite a demand from engine builders with whom we are dealing to know when we are going to adopt the standardization. Owing to our preliminary reports, the first one in May of 1900, and then again at Milwaukee in May of this year, some of the builders thought the matter was settled, and immediately started in to regulate their work by it. Unfortunately, we did not consider our work finished. We had sent out the preliminary state-

ment in order to find whether it met with general approval, and when we found that there were certain things that needed further adjustment, we made the necessary changes. I would like, therefore, to have some action taken by the Society, so that to people who ask, Is your work done? Has it been adopted or not? we could answer, Yes, it is practically settled. I believe it is a custom of the Society not to adopt any report, because the Society does not care to be responsible as a body for the reports of committees, but if the remarks made are favorable in a general way, and it appears that the report does meet with general acceptance by the members of the Society, that has the same effect as an actual vote definitely adopting it. Before we drop the subject, not necessarily to-night, but early to-morrow, I would like to have the matter taken up and have some expression of opinion, so that when the question is raised, as it certainly will be, as to when these recommendations are going into effect, we may be able to let people know.

NOTE BY THE SECRETARY.—The American Society of Mechanical Engineers has adhered steadfastly to a precedent established in the early years of its history, with respect to official action concerning the reports of its professional committees. The Society does not adopt, or even recommend, the standards or methods reported to it by its committees. The report is presented, accepted for record, and ordered printed in the *Transactions*, that it may be made publicly available. This action was taken in connection with the foregoing report.

No. 917.*

REPORT OF THE COMMITTEE ON STANDARD PIPE UNIONS. †

YOUR Committee, appointed to consider the subject of securing uniformity in the threads of coupling unions for pipe, in joint conference with similar Committees of the American Railway Master Mechanics' Association, and the Master Car Builders' Association, beg leave to report as follows:

After considerable delay in getting the Committee together, due largely to the special engagements of some of the members in Government service on account of the war with Spain, your Committee was finally organized with its present membership about two years ago, and immediately took up the work assigned to it with the corresponding Committees of the American Railway Master Mechanics' and Master Car Builders' associations.

It was found that the Committees of these associations were also considering two other matters, viz., uniform pipe threads, and standard square heads for bolts; and desired your Committee to proceed with the active consideration of the subject of uniformity in the threads of coupling unions for pipe.

A careful examination of the dimensions of the threads in the unions made by each of the principal manufacturers of these fittings showed that there were absolutely no two alike, and further, that the other dimensions of the unions were so affected by the dimensions of the threads in the coupling nut, that any successful attempt at uniformity in the threads must necessarily carry with it uniformity in so many of the other dimensions of the union itself, that this Committee would be obliged to take

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* Presented at the New York meeting, December, 1901, of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† The question treated in this report was presented to the Society by Messrs. E. M. Herr, W. H. Marshall, and C. H. Quereau, by an official letter of November 16, 1897, which was published in the *Transactions*, Volume XIX., page 29. The matter was referred to the Council by the Annual Meeting of December, 1897, and pursuant to favorable action by that body, the Committee was constituted as appears in this report. Reports of progress have been made during the interval, but this report presents the final opinions of the Committee.

up not only the dimensions of the threads, but of the entire coupling union.

A careful study of the design of all makes of unions now commonly used was then made for all sizes of pipe from $\frac{1}{8}$-inch to 4-inch inclusive. This investigation showed that no make of unions was sufficiently free from defects in all sizes when critically examined to warrant its adoption as a standard, even had it been considered desirable to do so; and your Committee then decided to undertake the complete design of commercial sizes of malleable pipe unions for wrought-iron pipe from $\frac{1}{8}$-inch to 4-inch inclusive, in order to get a design which we could endorse as consistent and submit as a proposed standard union. While this somewhat broadens the scope of your Committee's work, it seemed the only practicable way to comply with our instructions.

The details of the design were worked out under the personal direction of Mr. Vogt, of the Committee, who has prepared the data, drawings, and tables of dimensions accompanying this report, as follows:

Figs. 11 and 12 show a $\frac{3}{4}$-inch union drawn full size, with all dimensions numbered for reference to the accompanying Table I.

Table I. gives the dimensions of all sizes of unions from $\frac{1}{8}$-inch to 4-inch, the figures at top of column referring to corresponding dimensions on Figs. 11 and 12. The description accompanying Table I. explains this Table, and where any radical departure is made from present practice, it is explained and the reasons given briefly.

Fig. 13 is a diagram of dimensions of the proposed standard pipe unions, and shows all dimensions plotted to an arbitrary scale, the vertical dimensions representing tenths of inches, the horizontal the outside diameter of the pipe.

Figs. 14–27 show a longitudinal section, full-size, of each of the proposed standard pipe unions, through its axis and the middle of side of the nut.

It will be noted that all sizes from $\frac{1}{2}$-inch to 4-inch have the pipe and swivel ends panelled where the pipe wrench engages. This panelling is not put upon the smaller sizes, on account of the increase in size of the nut and dependent parts necessitated by putting the ribs on the ends, nor is it considered at all necessary on these sizes.

The mark S on the side of the nut (Fig. 27) is suggested for a designating mark which could be secured by this Society if it is deemed wise to pursue such a course. The Committee recommends that this be copyrighted and the standard unions thus designated.

Under date of March 16, 1901, your Committee, having completed the design of proposed standard unions, wrote the following letter to eleven of the principal manufacturers and dealers in malleable iron pipe unions:

The undersigned were appointed a Committee of the American Society of Mechanical Engineers to consider the matter of a standard union for ordinary sizes of pipe. After a thorough study of the situation, and finding that no two manufacturers of unions made these parts interchangeable, it was decided that, in order to establish a standard union, the Committee should proceed on lines entirely free from the consideration of any special sizes or dimensions now used by manufacturers, excepting that the part of the union which is screwed upon the pipe should conform with the Briggs Standard pipe threads, as recently recommended by this Society, the American Railway Master Mechanics' Association, and the Master Car Builders' Association. Acting upon this decision, a line of malleable unions has been designed, and we are enclosing you, under separate cover, the following in connection therewith:

One blue print from drawing No. 15427, showing dimensions of ½-inch and 2-inch unions.

One blue print, dated Altoona, Pa., June 15th, 1900, showing diagrammatically "Proposed Proportions for M. I. Pipe Unions" for all sizes of pipe from ⅛-inch to 4-inch inclusive.

One blue print from drawing No. 15009, showing ¾-inch union drawn double size and with all the dimensions numbered.

One copy "Description Accompanying Table of Malleable Pipe Unions."

One copy "Proposed Dimensions for Pipe Unions."

The dimension numbers on print from drawing No. 15009 have reference to the table of dimensions mentioned. We believe this information will enable you to clearly see just what the Committee proposes to submit to the Society as a design for standard malleable iron unions. Before formulating our report, we cordially invite you, as a manufacturer of unions, to favor the Committee with any suggestions, criticisms, or advice you may be able to give, in any way affecting these unions, either from the manufacturers' standpoint, or the standpoint of the dealer in, or user of these devices.

Thanking you in advance for any consideration you can give to this matter, we remain.

Two of those receiving such letters favored the Committee with suggestions and criticisms, which were all carefully considered, and the design, modified in the light of these suggestions, was again submitted to the same parties under date of November 8, 1901, as follows:

The Committee appointed by the American Society of Mechanical Engineers, on Proposed Standard Unions, having received certain criticisms and suggestions from the manufacturers, to whom the proposed design was previously submitted, takes pleasure in sending you herewith the following prints, etc., showing the design as modified, after full consideration of the criticisms received, viz:

One print "Proposed Standard Pipe Unions," dated June 5, 1901, showing full-size section of proposed unions as modified by the committee.

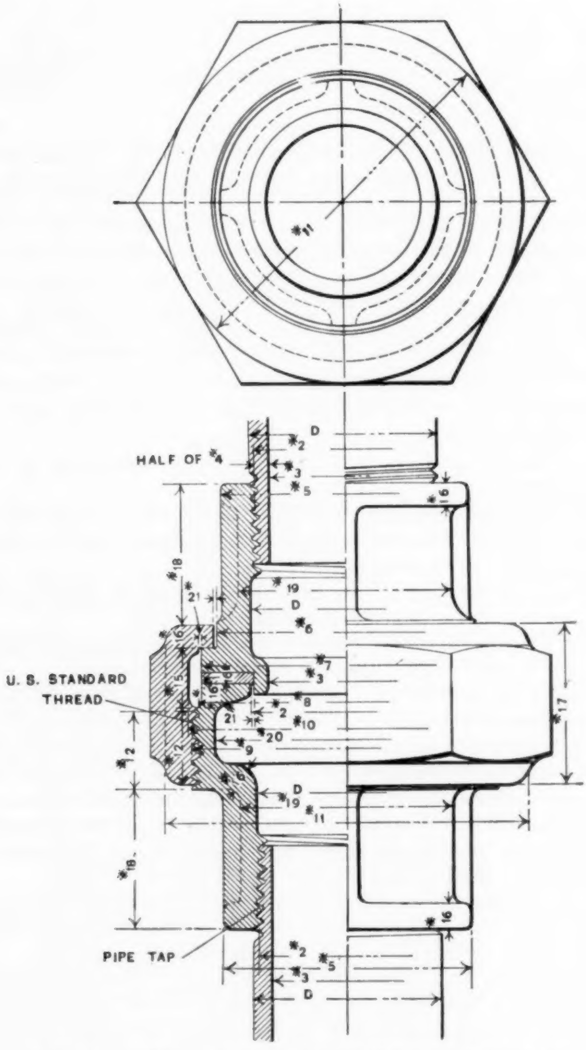


FIG. 11.—¾-INCH STANDARD PIPE UNION. FULL SIZE.

One blue print No. 15009-A, showing ¾-inch union, drawn double size, with all dimensions numbered.

One copy "Description Accompanying Table of Malleable Pipe Unions," dated November 7, 1901, explaining fully the dimension lines.

One copy table "Dimensions for Proposed Standard Pipe Unions," dated November 7, 1901, giving actual dimensions for each size of union.

One blue print showing modified diagram of dimensions, dated October 14, 1901.

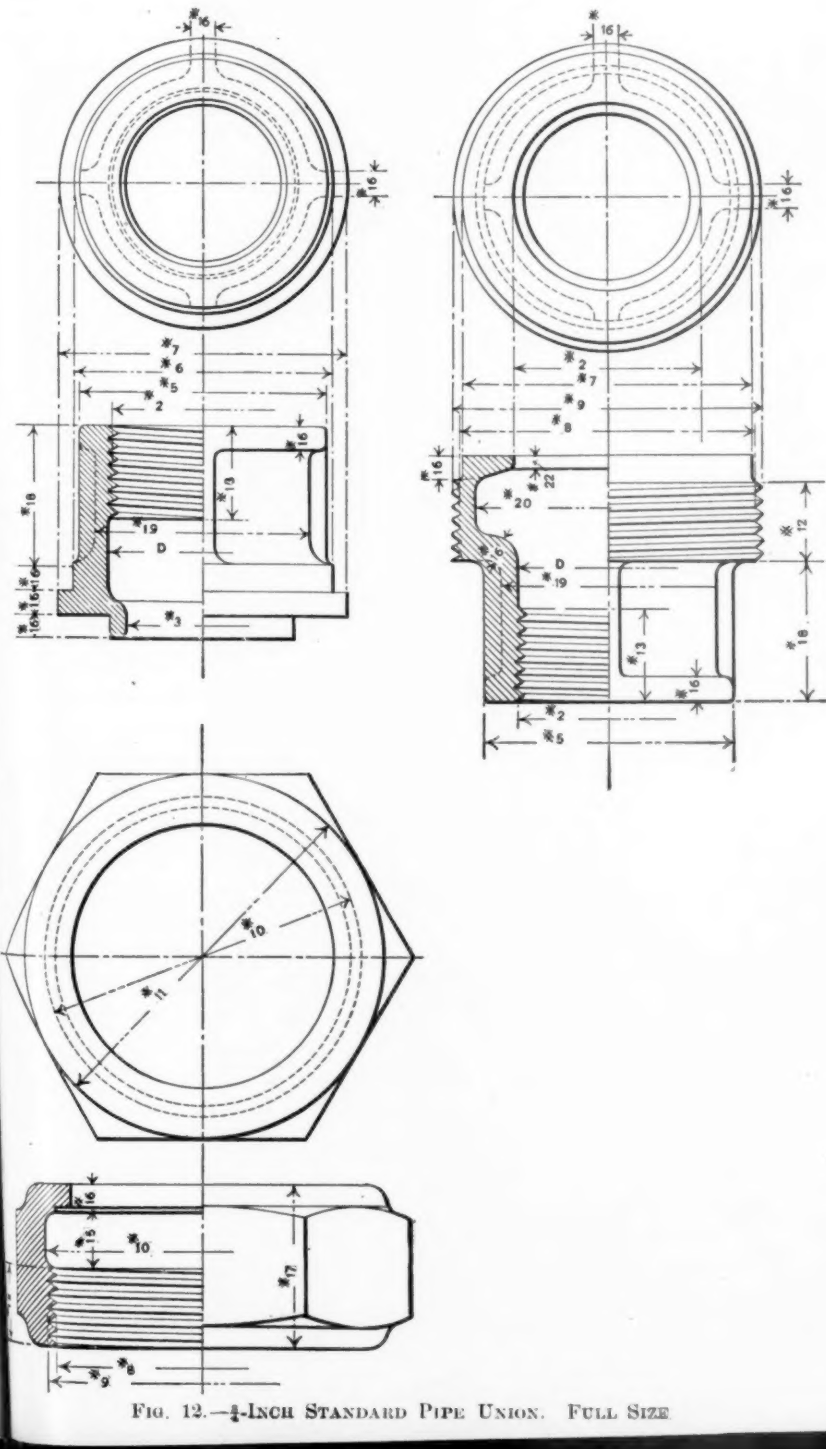


FIG. 12.—¾-INCH STANDARD PIPE UNION. FULL SIZE

We would ask you to again make a careful examination of this design as shown and favor us with any criticisms or suggestions which you may have to make, either from the standpoint of the manufacturer, dealer, or user of these devices. As it is the committee's earnest desire to submit their report to the Society at the next meeting, which occurs early in December, we would ask that you let us hear from you as promptly as possible.

Thanking you in advance for an early consideration of this matter, we remain.

To this communication, with the exception of acknowledgment of its receipt, no replies have been received.

Through the courtesy of Mr. Stanley G. Flagg, Jr., a number of ½-inch and 2-inch malleable unions have been made for your Committee from patterns prepared from the designs for proposed standard pipe union. These unions have been tested to destruction in two ways:

First. Tensile Test.—A round bar of iron, threaded with proper size pipe thread, was screwed into each end of the union, and a tensile strain was put upon it until rupture occurred. Where the casting was good, the breakage generally occurred from the sharp corner under the collar on the nut, or under the collar on swivel, indicating that the uniformity in strength aimed at in the design was probably affected by the sharp corner left by finishing the bottom of the nut and the collar on swivel end. The strength seems ample, however, so no change in the dimensions is recommended. The average breaking stress of eight pieces, ½-inch, was 11,200 pounds, minimum 9,850, maximum 12,080; of 2 inches, the average was 34,450 pounds, minimum 28,800, maximum 38,600.

Second. Transverse Tests.—Made by screwing a round bar of iron, threaded as before, into each end of union nut, these bars being of sufficient length to be supported 11 inches either side of the centre of the union, load being applied on centre of union nut. Breakage occurred at different points, indicating fairly uniform strength. The average breaking stress of three pieces, ½-inch, was 730 pounds, minimum 710, maximum 750; of 2 inches, the average was 7,930 pounds, minimum 7,800, maximum 8,000.

Bursting tests were also made with ½-inch and 2-inch unions by putting a pressure of water upon the union when fitted to piping. The pressure was gradually increased to 1,200 pounds per square inch, the maximum obtainable, with no failure, except some leakage under these pressures at the joint.

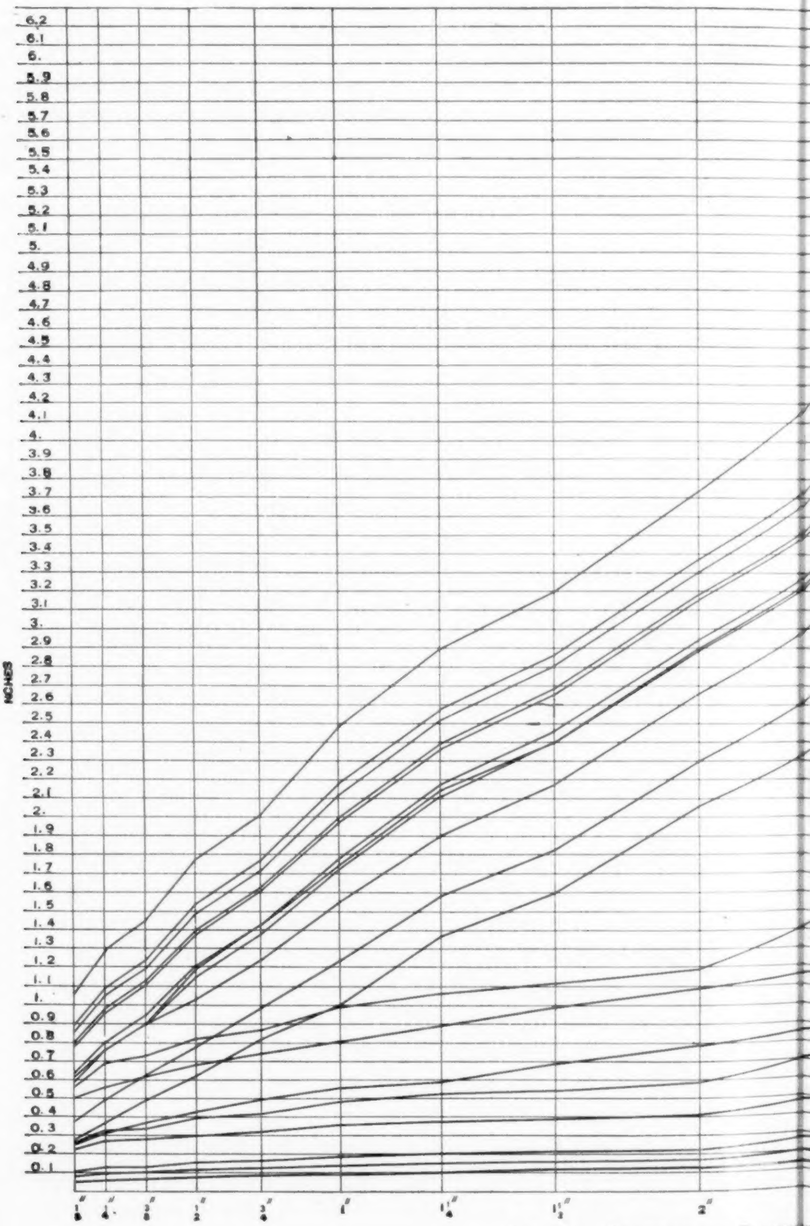
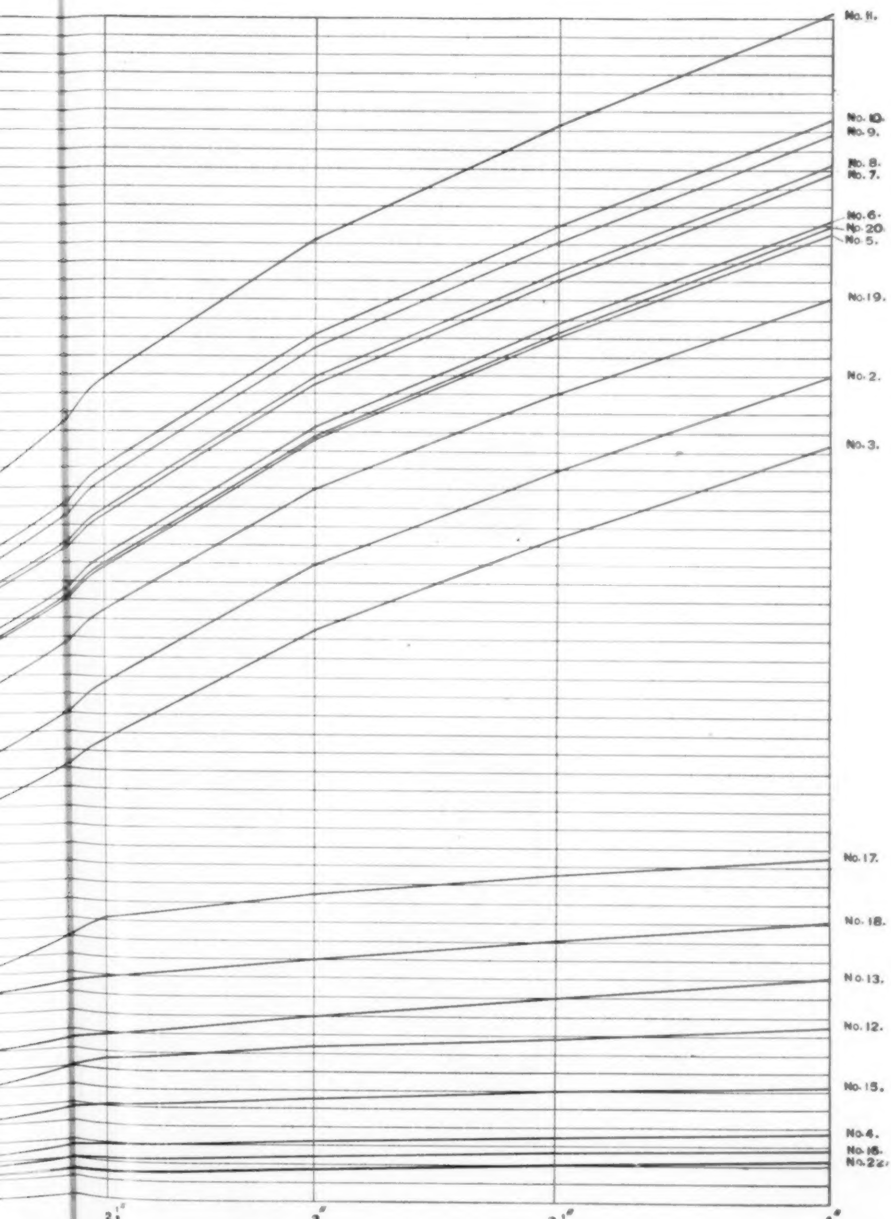


FIG. 13.—DIAGRAM OF DIMENS

XXIII,



Dimensions of Standard Pipe Unions.

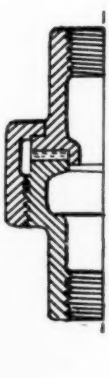


FIG. 14.—$\frac{1}{8}$-INCH.

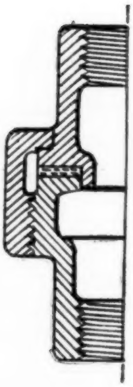


FIG. 15.—$\frac{1}{4}$-INCH.

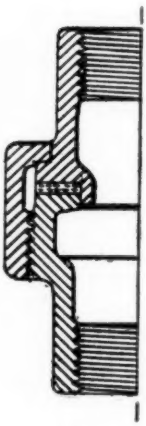


FIG. 16.—$\frac{3}{8}$-INCH.

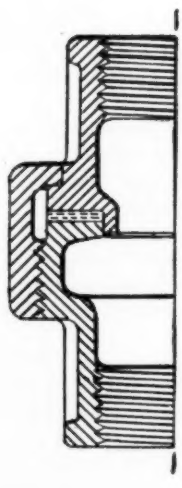


FIG. 17.—$\frac{1}{2}$-INCH.

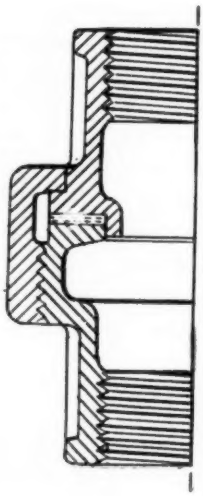


FIG. 18.—$\frac{3}{4}$-INCH.

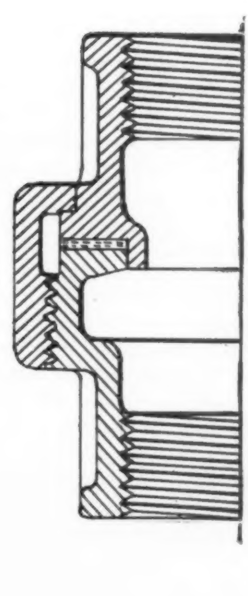


FIG. 19.—1-INCH.

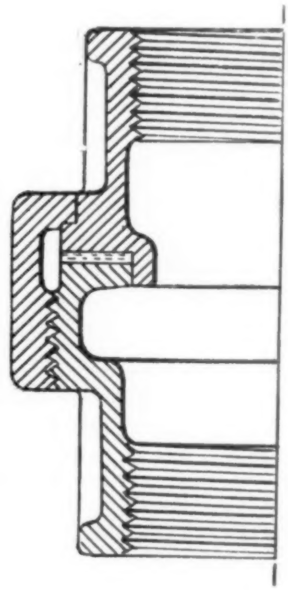


FIG. 20.—$1\frac{1}{4}$-INCH.

In order to secure and maintain the uniformity aimed at, if the report of this Committee be adopted, it will be necessary to have standard gauges prepared for the finished parts, *i.e.*, the thread and collar of the nut, the external thread and finished parts of the nose piece, and the external finished portions of the swivel. The threads for pipe connections are already established standards recommended by this Society being the Briggs standard for pipe threads.

The results of our work have been communicated to the Committees of the American Railway Master Mechanics' Association, and Master Car Builders' Association from time to time, and your Committee has been greatly aided by their assistance. We understand the designs submitted herewith will also be submitted to the railroad associations by their Committees at their next meeting.

Respectfully submitted,

E. M. Herr,
A. S. Vogt,
William J. Baldwin,
George M. Bond,
Stanley G. Flagg, Jr.

Description Accompanying Table I. of Malleable Pipe Unions.

Column No. 1 in Table I. represents the nominal diameter of pipe.

Column No. 2 represents diameter of pipe at one-half the height of full thread nearest solid section of pipe.

Column No. 3 represents the internal diameter of the pipe.

Column No. 4 represents the difference between Columns Nos. 2 and 3, and is equal to twice the thickness of metal in pipe measured from inside line to one-half the height of thread, as specified before.

Column No. 5 represents the outside diameter of end of pipe union and is taken as *No.* 2 *plus twice No.* 4 plus an arbitrary increment.

Column No. 6 is equal to No. 5 plus an increment varying from .04 to .07 of an inch. This increment was allowed for the purpose of being able to slip the nut over upper swivel end of union.

Column No. 7 is No. 6 plus an amount varying between .15 and .25. This lip created is considerably in excess of what exists on present pipe unions for the reason that we find the surface between the lip and the corresponding part of the nut is often damaged, and the bearing surface, when the full strength of the man is used on the wrench, is in sufficient. We assume that a man would pull about thirty pounds on a wrench, with a possibility of using less force on pipes of small diameters. For that reason we make a variation in the width of lip, which lip, theoretically, would be uniform for all sizes of pipe. The nut itself has been strengthened to prevent the lip from deflecting upward.

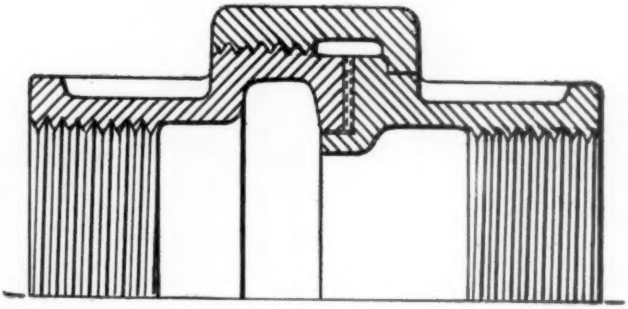


FIG. 21.—1½-INCH.

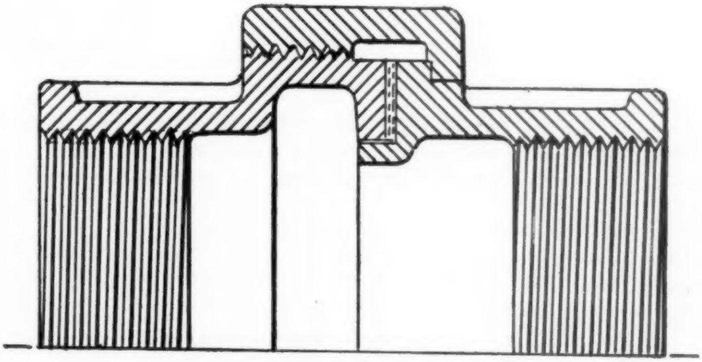


FIG. 22.—2-INCH.

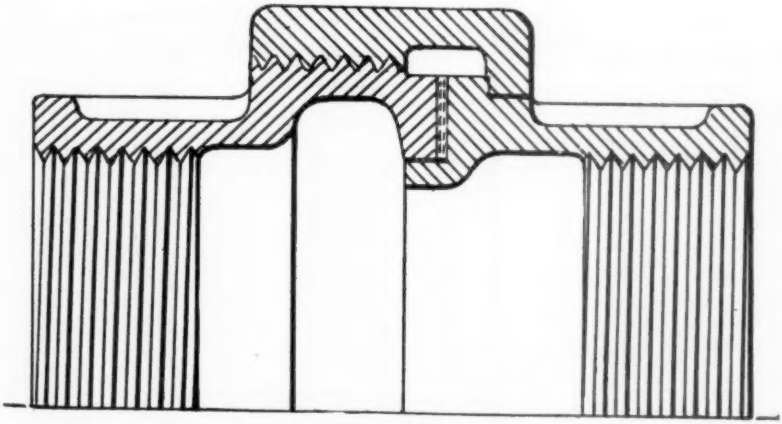


FIG. 23.—2½-INCH.

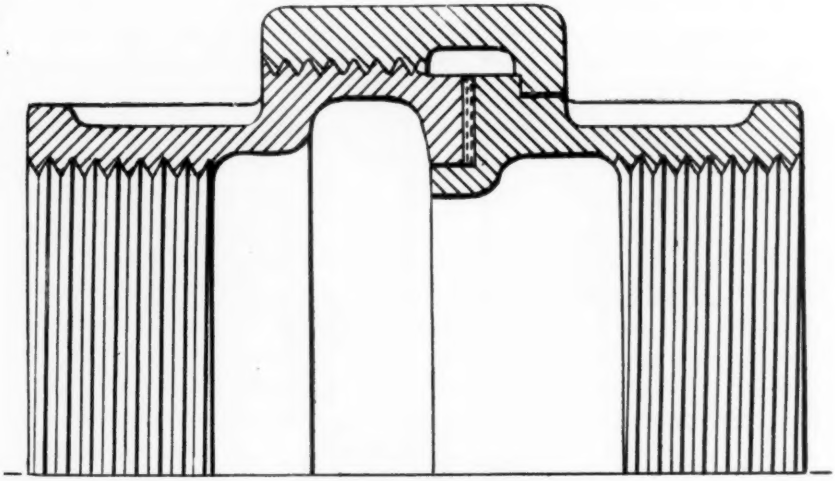


FIG. 24.—3-INCH.

Column No. 8 is No. 7 plus an increment varying from .02 to .04 of an inch.

Column No. 9 is No. 8 plus twice the height of the thread.

Column No. 10 is No. 9 plus an increment varying between .04 and .08 of an inch.

Column No. 11 is No. 10 plus one and one-half times No. 4.

Column No. 12 is two and one-half times No. 4, and was figured especially for bearing surface, so that the thread would not wear away too rapidly when the nut is occasionally removed.

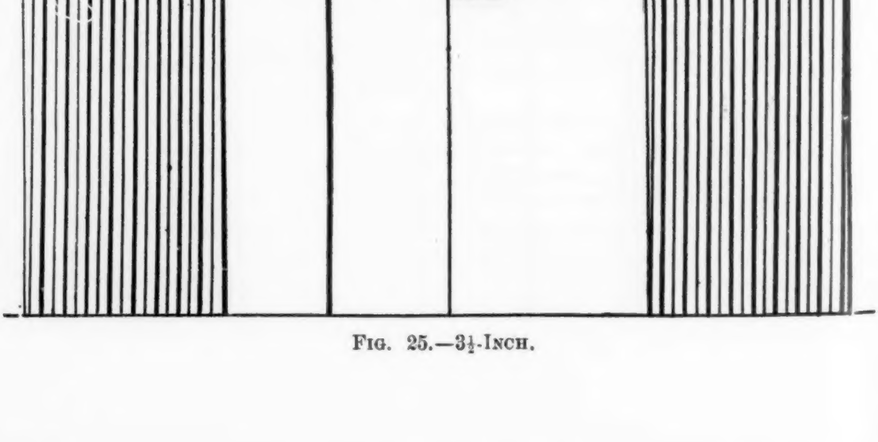


FIG. 25.—3½-INCH.

Column No. 13 has been assumed arbitrarily, but in all cases is greater than the length of full thread on standard pipe.

Column No. 14 represents the number of threads per inch in length of nut. This thread, we believe, should be United States Standard form and not sharp thread.

Column No. 15 is taken arbitrarily, but is based on the probable requirements of manufacturers for tapping out the nut.

Column No. 16 is three-fourths of No. 4.

Column No. 17 represents the full height of nut, and is equal to No. 12 plus No. 15, plus No. 16.

Column No. 18 is the amount of projection outside of nut.

Column No. 19 is No. 2 plus No. 4 plus an arbitrary increment.

Column No. 20 is No. 7 less No. 16 with slight modifications.

Column No. 21 represents the clearance at several points, as indicated on print.

Column No. 22 is assumed arbitrarily.

Approved by Mr. A. S. Vogt,
November 6, 1901.

Wilmerding, Penna.
December 2, 1901.

TABLE I.

Dimensions for Proposed Standard Pipe Unions.

1	2	3	4	5	6	7	8	9	10	11
1/8 inch	.375	.270	.105	.59	.63	.78	.80	.85	.89	1.05
1/4 inch	.496	.364	.132	.76	.80	.96	.98	1.05	1.09	1.29
3/8 inch	.630	.494	.136	.90	.95	1.11	1.13	1.20	1.24	1.45
1/2 inch	.783	.623	.160	1.16	1.21	1.38	1.40	1.49	1.54	1.78
3/4 inch	.992	.824	.168	1.38	1.43	1.61	1.63	1.72	1.77	2.02
1 inch	1.246	1.048	.198	1.74	1.79	1.98	2.01	2.13	2.19	2.49
1¼ inches	1.592	1.380	.212	2.12	2.18	2.37	2.40	2.52	2.58	2.90
1½ inches	1.831	1.610	.221	2.40	2.46	2.66	2.69	2.81	2.87	3.20
2 inches	2.306	2.067	.239	2.89	2.95	3.16	3.19	3.31	3.38	3.74
2½ inches	2.775	2.468	.307	3.39	3.45	3.67	3.70	3.86	3.93	4.39
3 inches	3.401	3.067	.331	4.07	4.13	4.36	4.40	4.56	4.63	5.13
3½ inches	3.901	3.548	.353	4.61	4.68	4.91	4.95	5.11	5.19	5.72
4 inches	4.4	4.026	.374	5.15	5.22	5.47	5.51	5.67	5.75	6.31

Approved by Mr. A. S. Vogt, November 6, 1901.

Dimensions for Proposed Standard Pipe Unions.

1	12	13	14	15	16	17	18	19	20	21	22
1/8 inch	.26	1/4	27	.2225	.08	.5625	1/2	.59	.615	.006	.05
1/4 inch	.33	5/16	18	.2625	.10	.6925	9/16	.76	.76	.006	.06
3/8 inch	.34	3/8	18	.2825	.11	.7325	5/8	.90	.905	.006	.07
1/2 inch	.40	7/16	14	.3025	.12	.8225	11/16	1.03	1.20	.006	.08
3/4 inch	.42	1/2	14	.3225	.13	.8725	3/4	1.24	1.43	.007	.09
1 inch	.49	9/16	11	.3625	.15	1.0025	13/16	1.565	1.76	.007	.10
1¼ inches	.53	.6	11	.3825	.16	1.0725	.9	1.91	2.15	.007	.11
1½ inches	.55	.7	11	.4025	.17	1.1225	1.0	2.18	2.40	.007	.13
2 inches	.60	.8	11	.4225	.18	1.2025	1.1	2.66	2.90	.008	.14
2½ inches	.77	.9	8	.5225	.23	1.5225	1.2	3.16	3.41	.008	.15
3 inches	.84	1.0	8	.5625	.25	1.6525	1.3	3.81	4.08	.008	.18
3½ inches	.88	1.1	8	.6025	.27	1.7525	1.4	4.31	4.63	.008	.20
4 inches	.94	1.2	8	.6225	.28	1.8425	1.5	4.81	5.19	.008	.22

Approved by Mr. A. S. Vogt, Nov. 6, 1901.

Wilmerding, Penna.,
December 2, 1901.

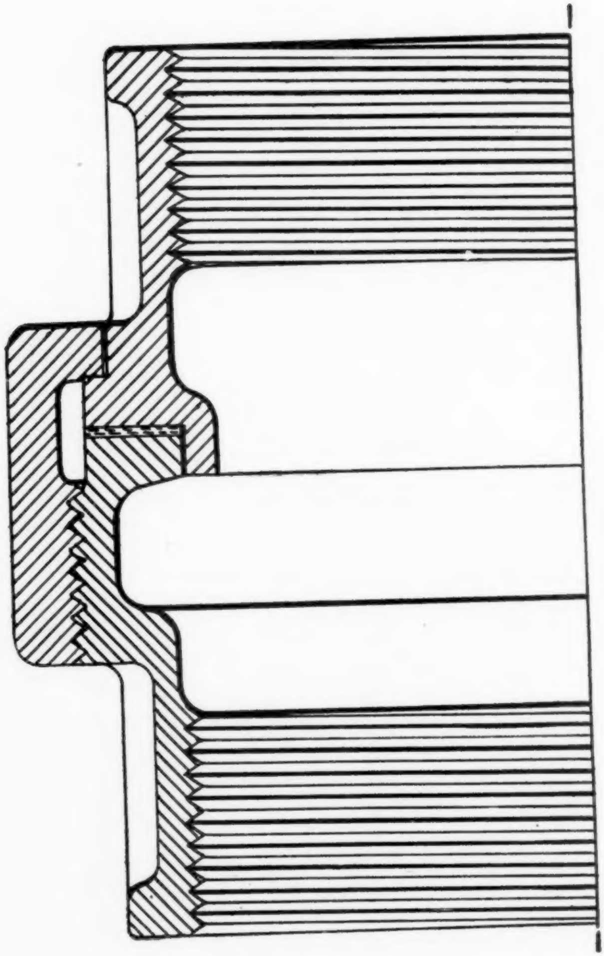


FIG. 26.—4-INCH.

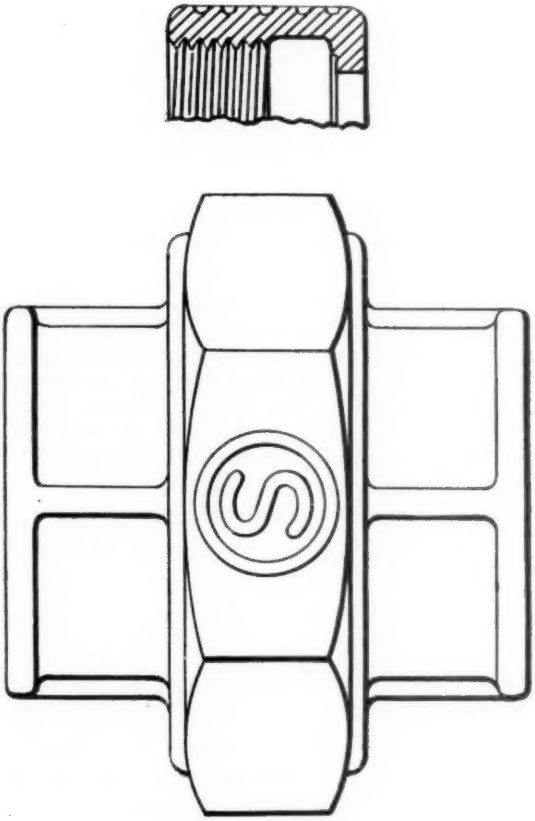


Fig. 27.

DISCUSSION.

Mr. William Kent.—I would like to ask Mr. Bond what was the object of taking a copyright on that report?

Mr. Bond.—The Committee considered it might be well to have a designating mark, if this design was adopted and generally recognized by the fittings associations or by the people who make or use pipe unions, so that those buying unions put upon the market having the letter "S" upon them would know they were the standard sizes, as recommended by this Committee, and having this special symbol copyrighted would prevent the unauthorized use of this designating mark.

Mr. Kent.—Only the trade mark?

Mr. Bond.—Just the letter "S" and its surrounding circle. That might be copyrighted and assigned to the American Society of Mechanical Engineers, and a license for manufacture under this copyright issued by the Society for a nominal sum, just as has already been done by the Society for the manufacture of the decimal gauge.

On motion, duly seconded and carried, the report was accepted and ordered to be printed in the *Transactions*.

NOTE BY THE SECRETARY.—The American Society of Mechanical Engineers has adhered steadfastly to a precedent established in the early years of its history with respect to official action concerning the reports of its professional committees. The Society does not adopt, or even recommend, the standards or methods reported to it by its committees. The report is presented, accepted for record, and ordered printed in the *Transactions*, that it may be made publicly available. This action was taken in connection with the foregoing report.

No. 918.*

WORKING LOADS FOR MANILA ROPE.†

BY C. W. HUNT.

(Member of the Society.)

1. THE technical reference books in use by engineers do not contain definite information in relation to the proper working loads for manila rope, when used in tackle blocks or for cargo hoisting. The hoisting of heavy weights is an important branch of erecting work, and I desire to record in the proceedings of the Society a statement of the result of an extended experience, together with some examples of the life of rope in actual service, which will be a guide to engineers in judging what service can reasonably be expected in similar cases.

2. The ultimate strength given in Table II. is materially affected by the age and condition of a rope in active service, and also it is said to be weaker when it is wet. Trautwine states that a few months of exposed work weakens rope 20 to 50 per cent. The ultimate strength of a new rope given in column *B*, Table II., is the result of tests made by the company with which I am connected of full-sized specimens of manila rope, purchased in the open market, and made by three independent rope walks. The results were given in a paper printed in volume xii., page 230, of the *Transactions* of this Society. Prof. B. Kirsch, of the Imperial Royal Technological Industrial Museum, in Vienna, has since broken over 200 specimens of rope, mostly 35 mm. ($1\frac{3}{8}$ inches) and 55 mm. ($2\frac{1}{8}$ inches) diameter, and his results agree within five per cent. with these figures. These tests demonstrated that within the limits of com-

* Presented at the New York meeting (December, 1901) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For further discussions on the same topic consult the *Transactions* as follows:

No. 426, vol. xii., page 230: "Rope Driving." C. W. Hunt.

No. 439, vol. xii., page 626: "Two-Rope Haulage System." R. Van A. Norris.

mercial sizes of hoisting rope, the full strength could be obtained for larger as well as for smaller sizes. When the strength falls off, the rope is imperfectly laid, or made on a machine too weak for the work. The ultimate strength of rope is, in this class of work, useful for one purpose only; that is, to estimate the factor of safety with any given working stress. The strength given is for ordinary commercial rope, which may be greatly exceeded in strength by rope made of selected materials. The strength given in Table II. can be depended upon as a reliable and safe guide in estimating the factor of safety for any case in hand.

3. The proper diameter of pulley-block sheaves for different classes of work, given in columns *F*, *G*, and *H* (Table II.) is a compromise of the various factors affecting the case. An increase in the diameter of sheave will materially increase the life of a rope. The advantage, however, is gained by increased difficulty of installation, a clumsiness in handling, and an increase in first cost. It can safely be assumed that the best size is one that considers the advantages and the drawbacks as they are found in practical use, and makes a fair balance between the conflicting elements of the problem. It would be rash for any one to attempt to make a decision from theoretical considerations; but an average of the practice of a large number of users working under all the various circumstances of financial stress or superabundance, of urgency or leisure, of mathematical analysis, or rule of thumb decisions, furnishes an acceptable basis for a decision as to the limits of good engineering practice. That average the table aims to give.

4. An abundance of data is available from which to draw a reasonable conclusion in the premises. A few typical illustrations will make clear the method of procedure, and also be of service in showing what changes in sizes or proportions an engineer, in any given case, could make to reach a higher efficiency of mechanism, or a greater commercial economy. In driving 28,908 piles on the Chicago, Milwaukee and St. Paul Railway, the engineering department kept an accurate account of the number of piles driven by each one of the 79 lines of various sizes of manila rope used. From this record the average number of piles driven by each size of rope was computed, and also the cost of rope per pile driven was ascertained. This account showed that for hammers weighing from 1,800 pounds to 2,600

pounds, $1\frac{1}{2}$-inch diameter rope was the best, and for hammers from 2,600 to 3,200 pounds, rope $1\frac{3}{4}$ inches in diameter should be used. Similar records covering many years have been kept by various coal dealers, of the diameter and cost of their rope per ton of coal hoisted from vessels, using sheaves of from 12 to 16 inches in diameter. These records show conclusively that, in hoisting a bucket that produces 900 pounds stress upon the rope, a $1\frac{1}{4}$-inch diameter rope is too small and a $1\frac{3}{4}$-inch rope is too large for economy. The size in general use for this work is $1\frac{1}{2}$ inches. The Pennsylvania Railroad Co. use $1\frac{1}{2}$-inch rope, running over 14-inch diameter sheaves for hoisting freight on all their lighters in New York harbor, and handle on a single part of the rope loads up to 3,000 pounds as a maximum Greater weights are handled on a 6-part tackle.

5. Robert Grimshaw, in 1893, in collaboration with Lieut. J. A. Bell, of the Equipment Bureau, U. S. N., made a series of tests at the Brooklyn Navy Yard on sheaves of various diameters and with various loads. "The rope was ordinary manila, 3 strand, $3\frac{3}{4}$ inches in circumference, such as is used in the United States Navy. It was dry, and tested on a 'cat and fish' tackle constituting a 6-fold purchase; sheaves were 8 inches in diameter, the three upper ones having roller bearings and the three lower ones plain solid bushings. The lower block and hook weighed 75 pounds." The result of these tests, so far as they are pertinent to this paper, are given in Table I.

6. It is interesting to compare the life of a rope when used with the stresses and sheaves given in columns *C* and *F* (Table II.) with one when used with those of columns *D* and *G*. To illustrate this, take two cases using exactly the same size and quality of rope; one to be worn out in hoisting coal from vessels, with stresses and sheaves as per columns *D* and *G*, and the other to be used on a rope drive with the stresses and sheaves as per columns *C* and *F*; all the wear on the rope comes from its internal friction in bending over sheaves, and its external chafing in running on and off them. A record of the number of bends made by each of the ropes during its life will be a convenient means of comparison. A rope $1\frac{1}{2}$ inches in diameter usually hoists from a vessel from 7,000 to 10,000 tons of coal on a well-arranged hoist. The rope will have a working stress of from 850 to 900 pounds running over three sheaves, one 12 inches and two 16 inches in diameter; in hoisting 10,000 tons it makes

20,000 trips, bending in that time from a straight line to the curve of the sheave, or *vice versa*, 120,000 times. The rope, when this service is completed, is worn out and must be replaced by a new one.

7. To illustrate the endurance of the rope used in the transmission of power, take a tin-plate mill transmitting 1,000 horsepower to the rolls by means of 1½-inch diameter manila ropes. In one particular case the sheaves are 5 feet and 17 feet in diameter and 36 feet apart, centre to centre. The rope is 86 feet long, runs 5,000 feet per minute, making 13,900 bends per hour, or more bends in 9 hours' service than the other rope made in its entire life. As is well known, the life of a transmission rope is measured by years, not hours. This enormous difference in the life of ropes of the same size and quality is wholly gained by reducing the stresses on the rope and increasing the diameter of the sheaves.

8. The weakening effect given in Table III. of various knots, hitches, and bends used in rope tackle is based upon experiments made in the laboratory of the Massachusetts Institute of Technology. Forty-five pieces of 2½-inch circumference, three-strand manila rope, cut from one coil, were broken in sets of from three to seven ropes, each rope of a set having the same fastening, and the average strength of each set being computed. Each different set tested some one of the fastenings in common use. The results were not erratic, but consistent, and from them a safe conclusion can be drawn. In examining the various knots broken, it is evident that those fastenings in which the standing part makes a short bend over another part of the rope are the weakest. Those like a round turn and a half-hitch, or a timber hitch, have a less abrupt bend in the standing part, and are materially stronger. With care, an eye in the end of a rope having the ends of the strands tapered down, can be spliced over an iron thimble so that it will have substantially the full strength of the rope; but as an eye is usually made it is not so strong, for which due allowance is made in the table. The same remarks apply to a splice in a rope. In the table some knots are included which were not tested, but whose approximate strength is evident from their formation. The table is to be used only as a guide in estimating the factor of safety. The loss of efficiency by the use of these knots was conclusively settled by the experiments above-mentioned, and the numerical value

TABLE I.

FROM GRIMSHAW REPORT.

Net Load on Tackle Weight Raised.	Theoretical Amount Required to Raise the Net Weight.	Actual Power Required.	Extra Power Required over the Theoretical.	
600 pounds.	100 pounds.	158 pounds.	58 lbs.	58 p. c.
800 "	133.3 "	198 "	64.3 "	48 "
1,000 "	166.7 "	243 "	76 "	45.8 "
1,200 "	200 "	288 "	88 "	44 "

TABLE II.

WORKING LOAD FOR MANILA ROPE.

A.	*B.*	*C.*	*D.*	*E.*	*F.*	*G.*	*H.*
Diameter of Rope, Inches.	Ultimate Strength, Pounds.	WORKING LOAD IN POUNDS.			MINIMUM DIAMETER OF SHEAVES IN INCHES.		
		Rapid.	Medium.	Slow.	Rapid.	Medium.	Slow.
1	7,100	200	400	1,000	40	12	8
$1\frac{1}{8}$	9,000	250	500	1,250	45	13	9
$1\frac{1}{4}$	11,000	300	600	1,500	50	14	10
$1\frac{3}{8}$	13,400	380	750	1,900	55	15	11
$1\frac{1}{2}$	15,800	450	900	2,200	60	16	12
$1\frac{5}{8}$	18,800	530	1,100	2,600	65	17	13
$1\frac{3}{4}$	21,800	620	1,250	3,000	70	18	14

TABLE III.

THE EFFICIENCY OF KNOTS IN A PERCENTAGE OF THE FULL STRENGTH OF THE ROPE, AND THE FACTOR OF SAFETY WHEN USED WITH STRESSES, AS PER COLUMN *E*, TABLE II.

I.	*J.*	*K.*	*L.*	*M.*	*N.*	*O.*	*P.*
	Eye-splice over an Iron Thimble.	Short Splice in the Rope.	Timber Hitch, Round Turn, and Half-hitch.	Bowline Slip Knot, Clove Hitch.	Square Knot, Weavers' Knot, Sheet Bend.	Flemish Loop, Overhand Knot.	Rope Dry. Average of Four Tests from the Same Coil as the Knots.
The efficiency of the knot.	90	80	65	60	50	45	100
Factor of safety . .	6.3	5.6	4.5	4.2	3.5	3.1	7

fixed within such narrow limits that the results cannot safely be ignored in executive work.

9. It will be understood that a table of working loads must be a general one, covering ordinary cases arising in practice. Local conditions may be such as to make it advisable to vary from the stresses given in the tables. In cases of great importance an engineer should carefully investigate the subject in detail, and then decide upon the exact stresses that he will put on his tackle, but ordinary cases are fully covered by the data given in the tables herewith.

In this table the work required of the rope is, for convenience, divided into three classes—"rapid," "medium," and "slow," these terms being used in the following sense:

"Slow"—Derrick, crane, and quarry work; speed from 50 to 100 feet per minute.

"Medium"—Wharf and cargo, hoisting 150 to 300 feet per minute.

"Rapid"—400 to 800 feet per minute.

The diameter of the rope in column *A* is obtained by dividing the girth by 3.1416. This method gives for a three-strand rope nine-tenths, and for a four-strand ninety-three hundredths of the diameter of a circumscribed circle. The girth method corresponds closely to the circular diameter of the rope when under stress, and is the most convenient and practical method of measuring.

No. 919.*

WATER POWER† DEVELOPMENT AT HANNAWA FALLS.

BY WALLACE C. JOHNSON, NIAGARA FALLS, N. Y.

(Member of the Society.)

1. THE most important factor which has contributed towards the preëminence of the State of New York, among the States of the Union, is the waters of the streams flowing through her territory or along her borders. The streams have formed the harbors on lakes and ocean, and themselves furnish waterways for internal commerce. Wherever falls and rapids render them unnavigable, power may generally be derived for manufacturing. The most important source of power is in the waters of the Great Lakes as they flow through the Niagara and St. Lawrence rivers.

The second in importance as a source of power is the drainage from the elevated forests of the Adirondack Mountains. Here are upwards of 11,000 square miles, 800 feet or more above the level of the Hudson at Albany, and 500 feet or more above the St. Lawrence and Lake Champlain. The amount of power which it is practicable to obtain from the water flowing from this vast area in its descent to the lower levels is very great,

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* Presented at the New York meeting (December, 1901) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For previous discussions on this topic, Power Plant, consult *Transactions* as follows:

No. 483, vol. xiii., p. 331: "Notes on a Problem in Water Power." John Richards.

No. 583, vol. xv., p. 669: "A New Form of Canal Waste Weir." John R. Freeman.

No. 665, vol. xvii., p. 41: "Water Power: Its Generation and Transmission." Samuel Webber.

No. 666, vol. xvii., p. 58: "Water Power: Caratunk Falls, Kennebec River, Maine." Samuel McElroy.

No. 787, vol. xix., p. 839: "Some of the Mechanical Features of the Power Development at Niagara Falls." Coleman Sellers.

and is a natural resource of great value. The State of New York, by establishing a forest preserve covering substantially all of this area, has insured its preservation as a source of power.

2. The legislature now has it in its power to double the value of this great resource by passing a law which will permit the construction of reservoirs within this forest domain under proper restrictions. The largest river to draw its water from this region is the Hudson, which drains 4,000 square miles of this forest, not including the water received from the Mohawk. The second is the Raquette River, which drains an area (shown on Fig. 28) of upwards of 1,100 square miles. This drainage area is nearly all within the great elevated plateau lying on the north slope of the Adirondacks at an elevation of from 1,200 to 1,600 feet above the sea level. In this tract are Long Lake, Raquette Lake, Tupper Lake, Little Tupper Lake, Jordan Lake, and many other smaller lakes and ponds. The entire area is practically free from steep slopes and much of it is of a swampy nature. These lakes and swamps form natural reservoirs, which have a very considerable effect in equalizing the run-off. I know of no stream in the eastern part of the United States which has so large a low-water flow in proportion to the area of country drained as the Raquette. The flow at Colton, the point where the Raquette crosses the 800 feet elevation line, seldom falls below 1,000 cubic feet per second, though the drainage area above this is but little more than 1,100 square miles. The minimum flow of the rivers of the State, in proportion to area drained, will hardly average more than one-third this amount, and in several cases it is not more than one-eighth to one-tenth. The Raquette River is further remarkable in that it has a drop of about 300 feet in the first three miles of its course below Colton, and a further fall of 85 feet in the next two miles of its course.

3. The land and water rights along this part of the river have been acquired by the Hannawa Falls Water Power Company. The lower 85 foot fall has been developed first. A dam has been built at the village of Hannawa Falls, which forms a pond two and one-half miles long and covering about 200 acres. From this pond the water is conducted by a canal about 2,700 feet long to a forebay, thence by penstocks to the wheels. The tailrace extends about 2,000 feet down from the power house,

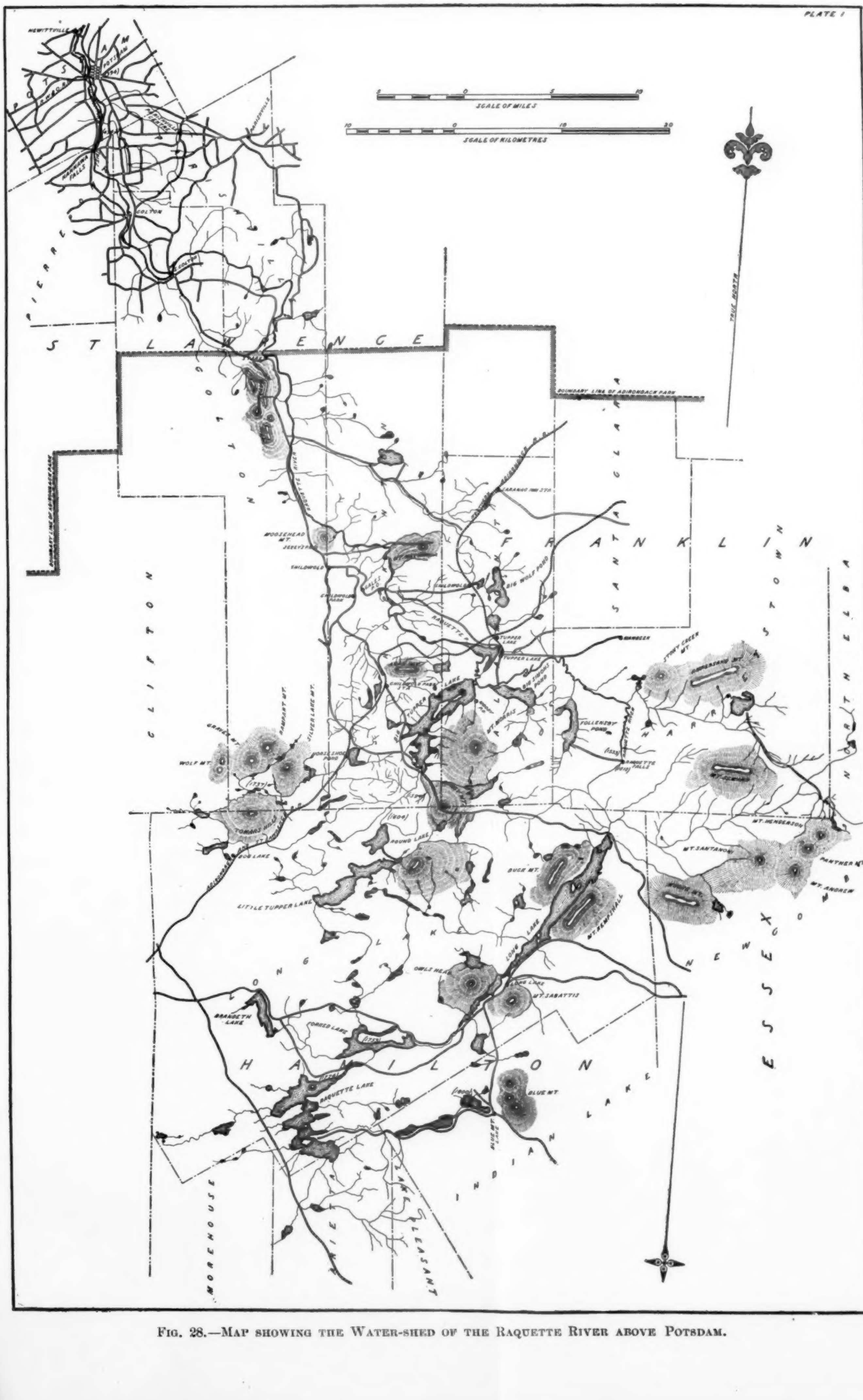


FIG. 28.—MAP SHOWING THE WATER-SHED OF THE RAQUETTE RIVER ABOVE POTSDAM.

being separated from the river by an embankment of earth and stone.

The location of the dam, forebay, power house, and tailrace is shown on Fig. 29. At the point selected for the dam, the bed of the river was entirely Potsdam sandstone, the strata dipping at an angle of about 30 degrees with the horizontal down stream. The banks of the river at this point were nearly perpendicular walls of sandstone about 375 feet apart, up to a level of about 10 feet below the crest of the dam.

4. The general plan of the dam and entrance to the canal is shown on Fig. 30. On the west bank of the stream a wing wall was built on top of the ledge forming that bank of the river, and on the down-stream face the wall was carried down to the river bed. This wing wall was carried to a height of 8 feet above the crest of the dam. From the back of this retaining wall a core wall of concrete 3 feet in thickness was built from the rock up to the level of about 6 feet above the crest of the dam. This core wall was about 85 feet in length, and ran back to a point where the level of the natural ground was above the top of the wing wall. From the back of the wing wall an earth fill was made on each side of the core wall having a top width of 8 feet and a slope on each side of two to one, making the connection between the wing wall and the natural bank. Running east from this wing wall the overflow dam proper was 234½ feet in length. Then another wing wall 8 feet in thickness, and an opening for waste gate 15 feet 6 inches wide, and another wing wall against the bank on the east side similar to the one on the west side above described, both 8 feet above the crest, completed the dam. A section of the overflow dam is shown on Fig. 31. The general level of the river bed was about 30 feet below the crest of the dam, but owing to the dip of the rock, the strata being very irregular, some points in the foundation of the dam were 40 feet below the crest. This irregularity, presenting as it did faces of rock nearly at right angles to the line of pressure, made the best foundation obtainable for the dam. No excavation was made, therefore, for a foundation, except to form a seat for the toe of the dam, as shown on Fig. 31. (See also Fig. 35.)

5. The materials for the construction of all the masonry work were obtained from the large quarries of the Potsdam Red Sandstone Company, which are located on the west bank of the river

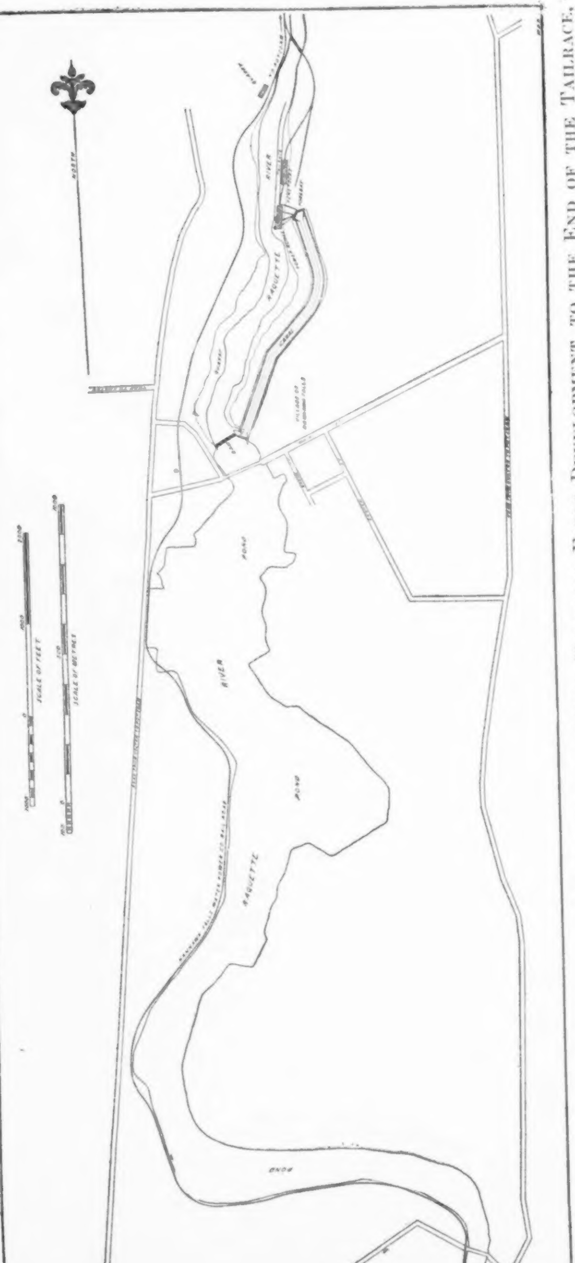


FIG. 29.—MAP OF THE RIVER FROM THE HEAD OF THE POND, HANNAWA FALLS DEVELOPMENT, TO THE END OF THE TAILRACE, SHOWING THE LOCATION OF THE DAM, CANAL, POWER HOUSE, AND RAILROAD CONNECTING WITH THE NEW YORK CENTRAL AND HUDSON RIVER RAILROAD AT POTSDAM.

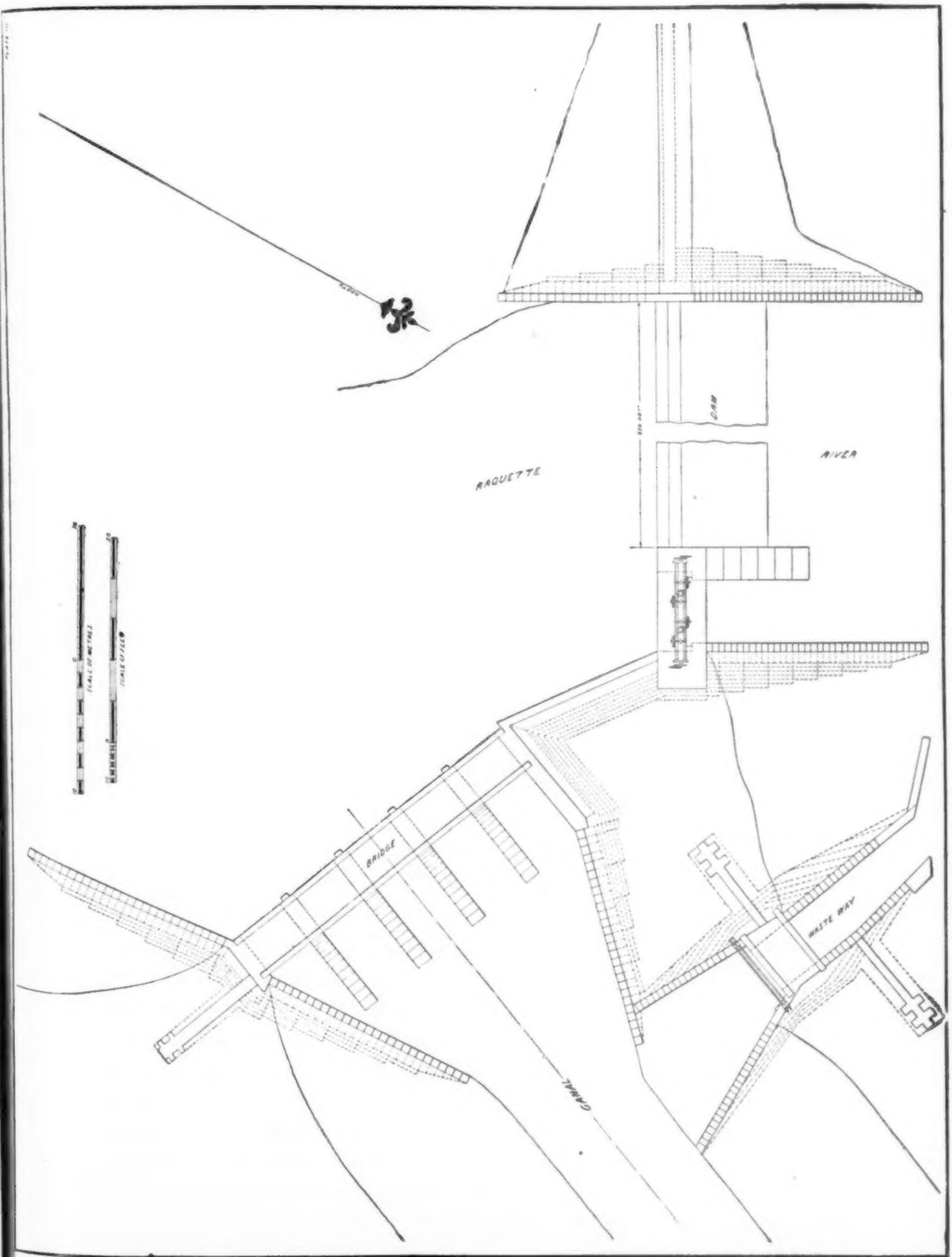


FIG. 30.—PLAN OF THE DAM AND THE HEAD OF THE CANAL, SHOWING THE LOCATION OF OVERFLOW, WASTE GATE, ENTRANCE TO CANAL, AND WASTE WAY FROM CANAL.

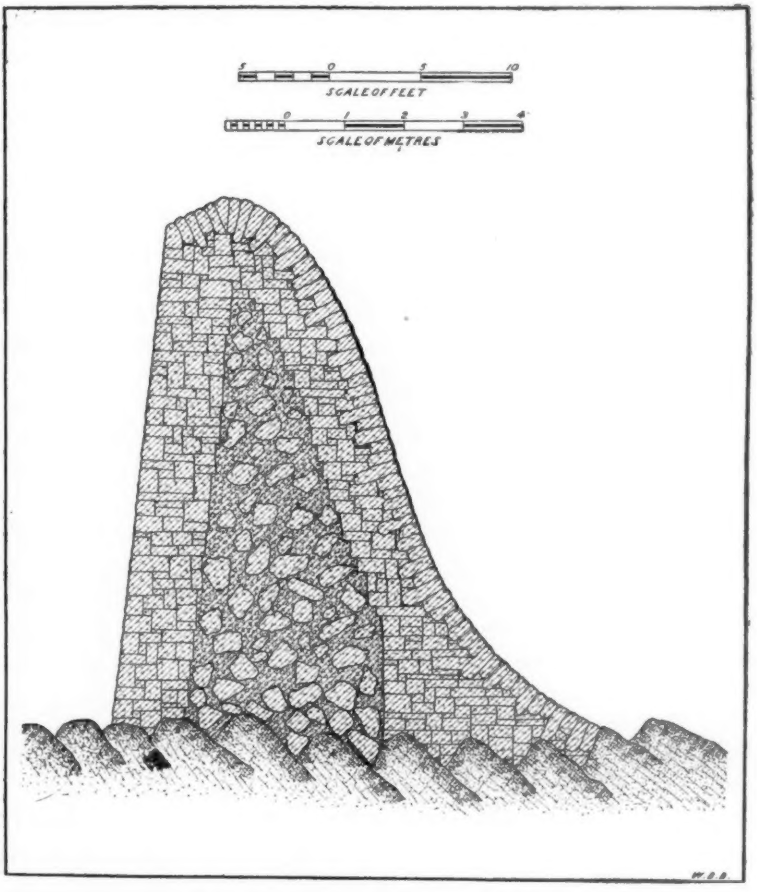


FIG. 31.—CROSS-SECTION OF THE DAM.

between the dam and the power house. This stone is obtained from the quarry with very level beds, and no cutting was done on any part of the work except to level the crest of the dam after the stone was in place. For the down-stream face of the dam, stones from 12 to 18 inches in thickness and not less than 2 feet wide and 3 feet to 6 feet in length were used, the beds being laid normal to the surface. For the up-stream face of the dam a rubble wall about 3 feet thick was laid of smaller stone. The space between was filled with large boulders and irregular shaped quarry stones with concrete rammed in around and between. Natural cement, Union brand, was used throughout except for laying the stone on the down-stream face of the dam,

where Giant Portland was used. Natural cement concrete was mixed in the proportions of 1 part cement, 2 parts sand, and 4 parts broken sandstone. The dam was completed in the fall of 1899, and has had 4½ feet of water on its crest in two different seasons. When the water is below the crest the dam is perfectly tight.

6. It was thought desirable to be able to control the level of the water in the pond, was necessary to provide for the passing of large quantities of logs by the dam, and was also desirable to have a means of discharging debris floating in the stream and preventing its entering the canal; for these reasons the 15½-foot space at the end of the dam was closed by a steel waste gate, shown in detail in Fig. 32. This gate consists of a steel frame closing the 15½-foot space, the sill being 30 feet below the crest of the dam. At the bottom are two openings, 6 feet wide and 8 feet high, which can be closed by gates operated by hydraulic cylinders. At the top are two other openings about 6 feet square, closed by gates which are opened by being pushed down, permitting as great a depth of water as desired to flow over the top of the gate. Both of these gates have worked very freely and accomplished the purpose for which they were designed.

7. The entrance to the canal is in the east bank of the pond, about 42 feet above the dam, the width of the entrance being 80 feet. For the purpose of permitting the canal to be closed, by means of stop-gates, four piers, 4 feet in thickness, were built at equal intervals in this 80-foot opening, leaving five openings, each 14 feet 7 inches in the clear, and arches were turned on these piers, forming an arch bridge across the entrance to the canal (Figs. 30 and 36). A little below the entrance to the canal is a waste weir and gate, by means of which the water can be drawn from the canal into the river, as shown in Fig. 30. This waste weir is also spanned by an arch bridge.

8. The canal, from the dam to the forebay, about 2,700 feet in length, is 20 feet in depth from the top of the banks, the bottom being 14 feet below the crest of the dam. The topography of the ground through which it passes is such that it was possible to lay out the canal so that for the greater part of its length it would be partially in excavation and partially in embankment, the material taken from the excavation being nearly all used in making the embankments. The bottom

width of the canal is 30 feet, the top width 110 feet, making the inside slopes two to one in all cases. The width of the top of the embankment is 8 feet, and the outside slopes $1\frac{1}{2}$ to 1. The materials excavated were, for the most part, a gravelly loam, overlying hard-packed sandstone chips and sand mixed with some clay, which, though hard to excavate, proved to be excellent material for embankment. Much care has been taken in letting water into the canal and in compacting the embankments. They are now entirely free from leakage. The outside of the banks, and the inside down to the water have been given a dressing of stable manure and sown with quack grass, which is now growing luxuriantly, presenting a very pleasing appearance,

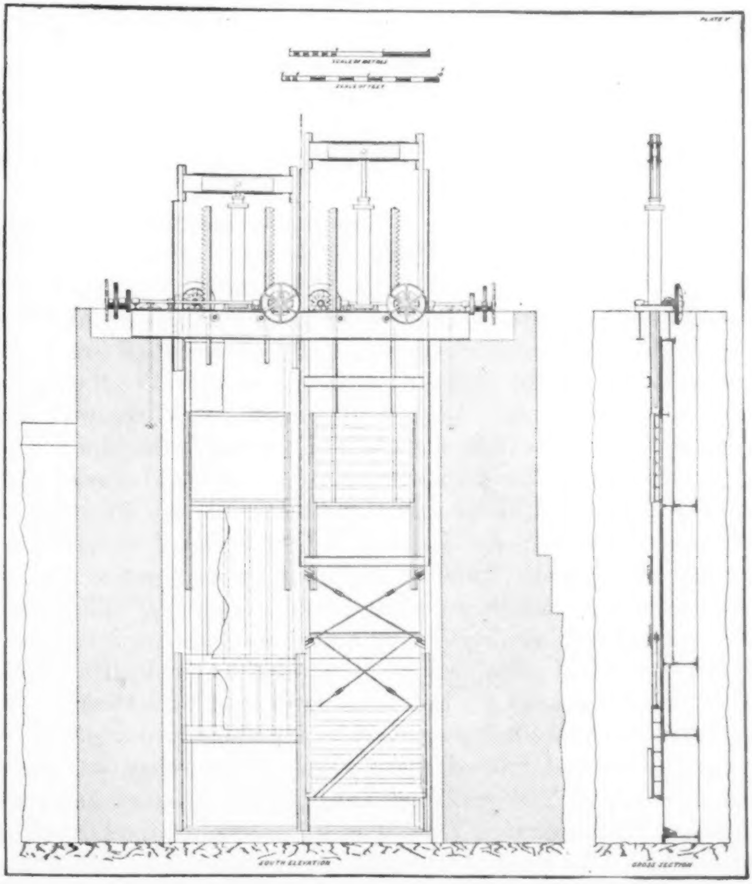


FIG. 32.—DETAIL PLAN OF WASTE GATE IN THE DAM.

as well as being of substantial benefit. The section of the canal was designed to carry 2,500 cubic feet per second of water, with a velocity of 3 feet per second, it being the intention to use that quantity of water when available.

9. It is also likely that the Hannawa Falls Water Power Co., together with other water power owners on the same river, will be able to construct reservoirs which will maintain a constant flow of 2,500 cubic feet per second in the river. The canal ends in a forebay (shown in Fig. 33), from which the penstocks lead down to the power house on the bank of the river below. At the entrance to the forebay the canal is some 4 feet in excavation, the balance is embankment. The ends of the banks are supported by retaining walls, to which the forebay walls are connected. From the retaining walls, core walls of rubble masonry from 4 to 6 feet thick, are run back into the centre of the embankment about 50 feet, and down to good material. To prevent water following along the face of the wall and so through the bank, three buttresses about 3 feet square are built on each side of the core wall.

10. The forebay walls are of a form and dimensions shown in Figs. 33 and 34. They are built of concrete having stone embedded in it, and the outside faced with sandstone blocks 6 to 8 inches thick and 10 to 12 inches deep. In the walls are embedded the ends of seven penstock pipes, six 10 feet and one 6 feet in diameter. The 10-foot pipes are enlarged to 12 feet in the upper 4 feet of their length. Around the outside, and flush with the masonry, is a band of 6 by 6 angle iron rivetted to the pipe. The penstocks are set 18 feet apart on centres; midway between each two is a buttress of stone masonry 4 feet wide and 2 feet thick. To the outer corners are fastened 6 by 6 angles, forming slides for the head gates. This arrangement leaves a space 2 by 14 feet for the free admission of air to the penstocks. The gates are of wood and are hoisted by a rack and pinion, being connected to one main shaft, which is operated by an electric motor. In front of the gates are the racks supported by a steel frame, the gates and racks being covered by a wooden building.

11. The natural ground upon which this forebay was built was fine sand. The walls go down to the boulder hardpan, found at depths varying from 3 to 10 feet below the bottom of the forebay. To prevent any leakage of water under the walls, the entire bottom of the forebay has been filled to a depth of

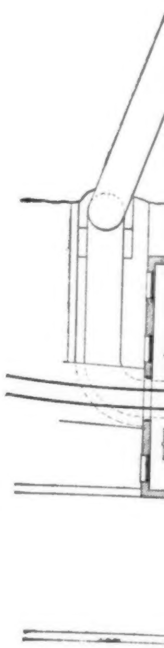
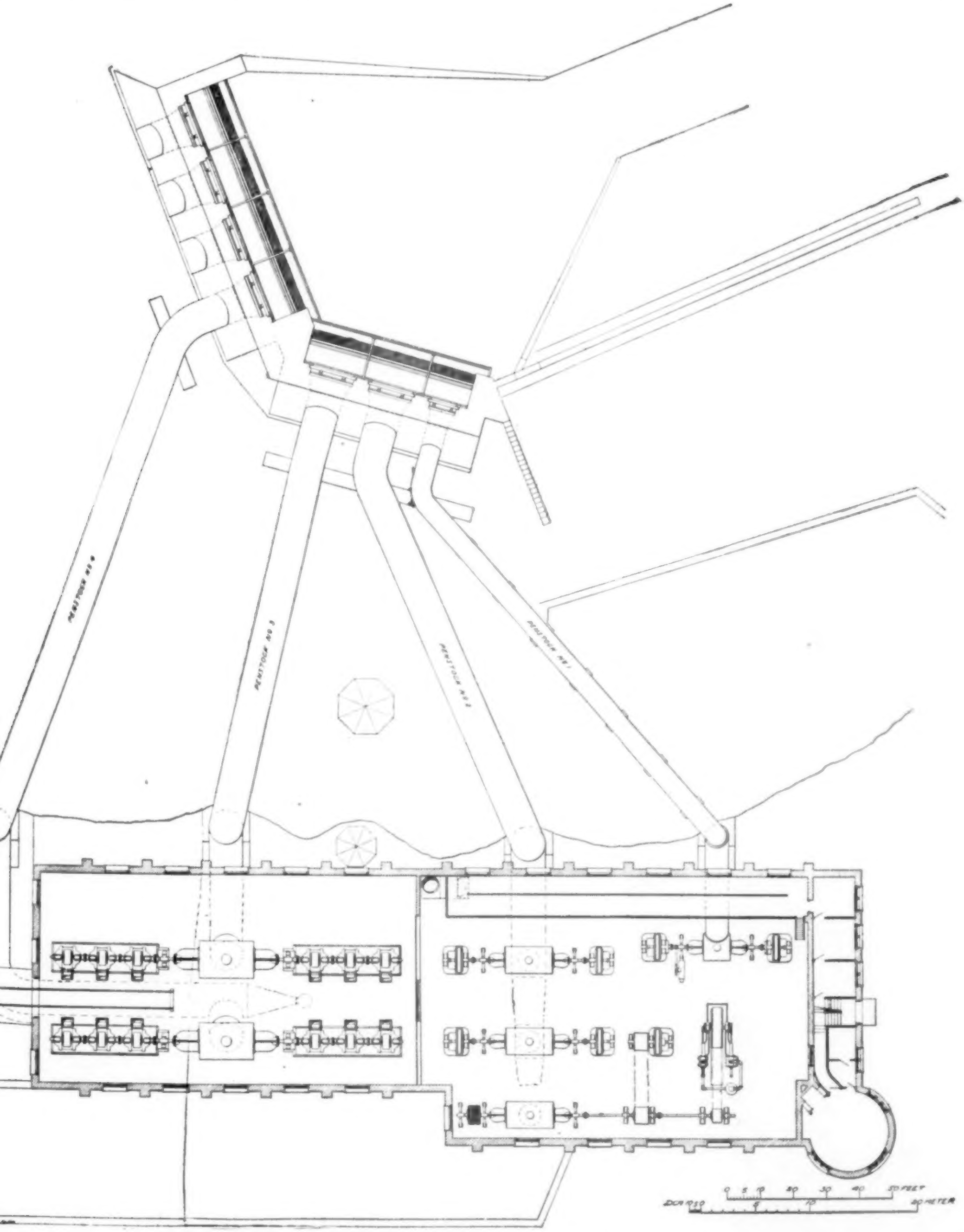


FIG. 33.—PLA



—PLAN OF THE LOWER FLOOR OF THE POWER HOUSE AND PULP MILL, SHOWING ALSO THE PENSTOCKS AND FOREBAY.

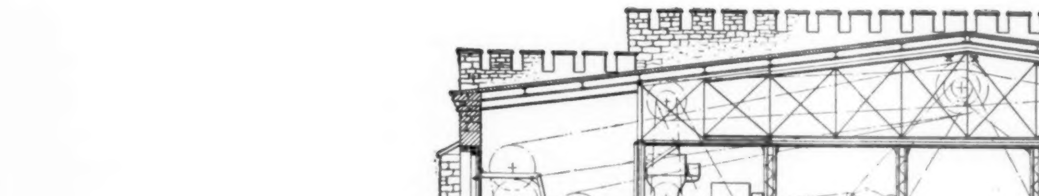
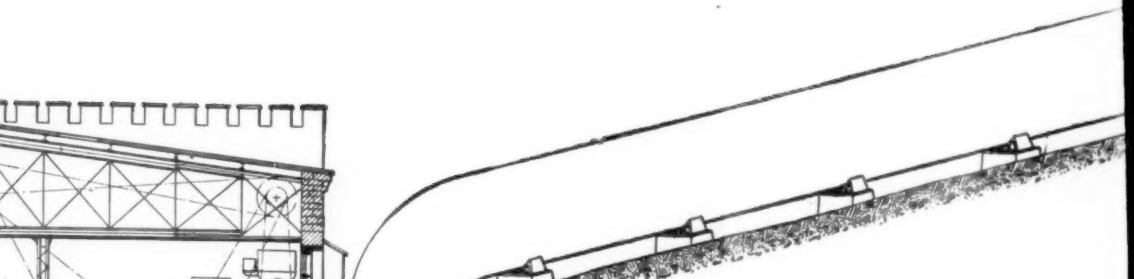
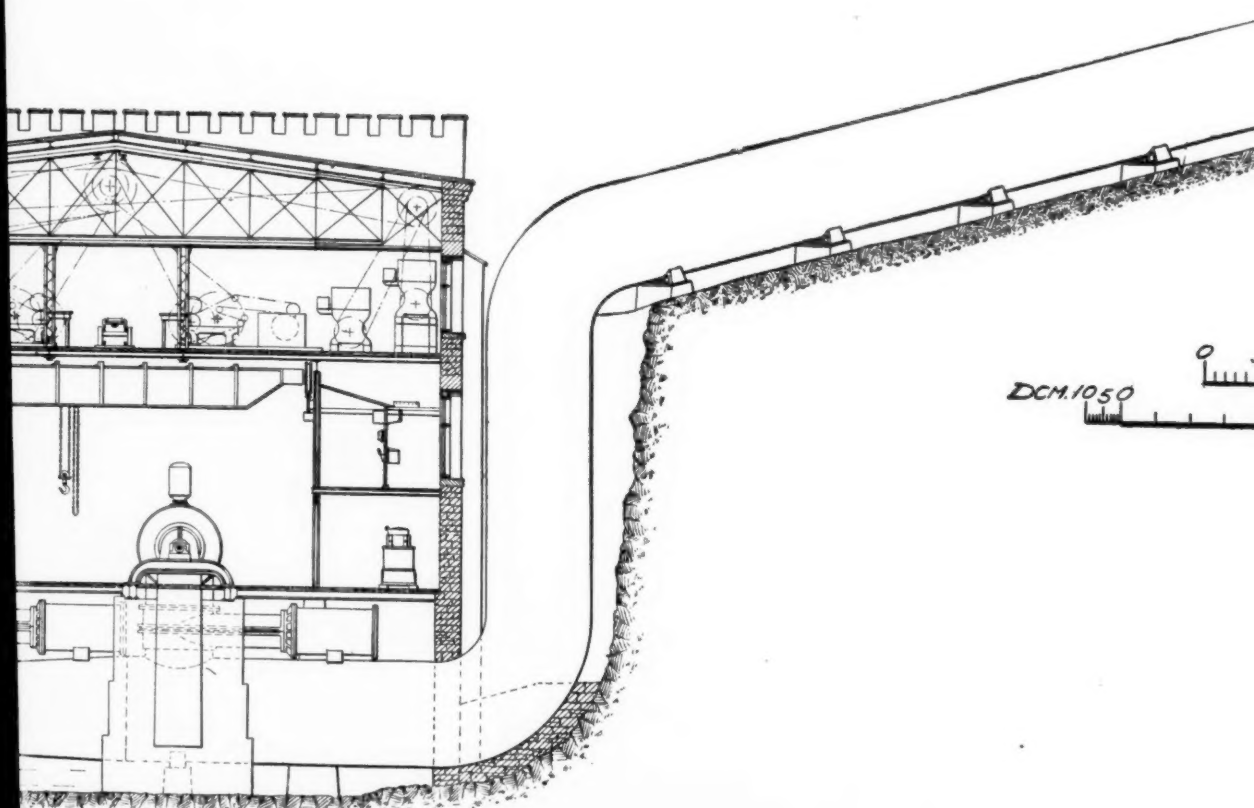


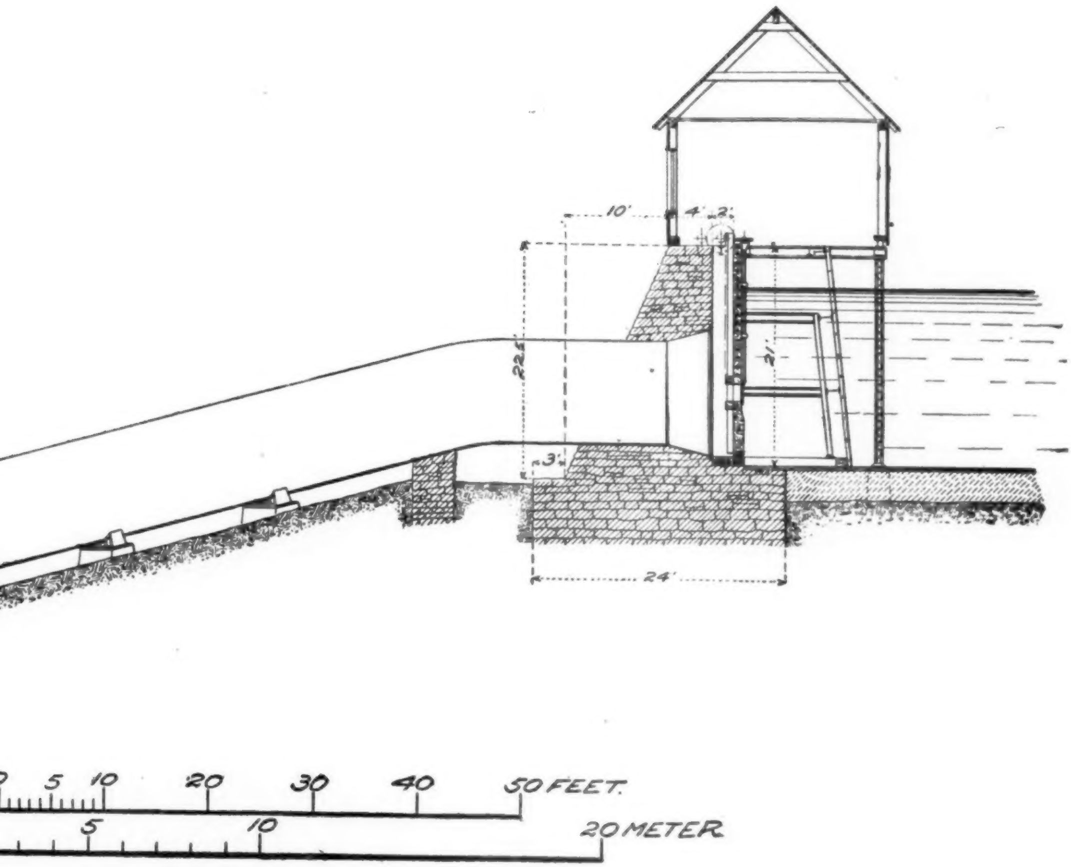
FIG. 34.—CROSS-SECTION OF THE POWER HOUSE AND FOREBAY ALONG PENSTOCK



TOCK NO. 2, SHOWING THE WATER WHEELS, SWITCHBOARD GALLERY, AND WET MACHINE AND SCREEN ROOM OF



LONG PENSTOCK No. 2, SHOWING THE WATER WHEELS, SWITCHBOARD GALLERY, AND WET MACHINE AND SCREEN ROOM C



...OOM OF PULP MILL; ALSO THE HEAD GATES, RACKS, GATES, ETC., IN THE FOREBAY.

FIG. 35.—PHOTOGRAPH OF THE DAM FROM THE DOWN-STREAM SIDE, WITH THE WATER BELOW THE CREST, SHOWING THE SHAPE AND CONSTRUCTION OF THE DAM, ALSO THE WASTE GATE AT THE EXTREME LEFT.

about 3 feet with clay, packed by water, and on top of this is about 4 inches of concrete, in which expanded metal has been embedded. This concrete and expanded-metal lining is also carried back 50 feet into the canal (Fig. 38), on the bottom and sides of the canal, and attached to the top of the wing walls, as they follow the slope of the bank. Where the concrete and metal lining is put on the sides of the embankments, 3 by 10 inch planks were set up edgewise and embedded in the earth, the length being up and down the bank, the expanded metal being fastened to the edge of the planks before the concrete was put on. These precautions were considered necessary on account of the treacherous material on which the forebay was built, and they have proved entirely efficient, as there is no leakage whatever from the forebay.

12. About 100 feet in front of the forebay is the high bank of the river, the water of which, at that point, is about 75 feet below the crest of the dam. Between the water of the river and the face of the high bank was sufficient room for the power house. At that point a building 250 feet in length by 60 feet in width for one-half its length, and 75 feet in width for the balance, two stories high, has been built. The floor of this power house is 72 feet below the crest of the dam. The tailraces (Fig. 41) have been excavated so that the water in them stands 12 feet below the floor, when the wheels are running, giving a working head of 84 feet on the wheels.

13. The building (Figs. 39 and 40) is constructed entirely of Potsdam sandstone and steel. The floors are concrete with expanded metal, and the roof is built of sandstone flags, 2 inches in thickness, laid on T-irons. The lower floor is 22 feet in clear, and is served by a travelling hand-crane of 16 tons' capacity. The upper floor is 10 feet in clear below the bottom chords of the trusses. A space 12 feet wide across the up-stream end of the building, including the tower at the southwest corner, has a mezzanine floor between the first and second stories, which is used for offices. The lower floor of the building, at the south end, a room 115 feet long by 75 feet wide, is the electric station. A space 12 feet in width, along the east side, the floor of which is on the same level as the office floor, is used as a switchboard gallery, the space underneath being used as a transformer room. At the south end of the room and on the east side, is a 1,250 horse-power water wheel, fed by the 6-foot penstock mentioned above, to either end of which

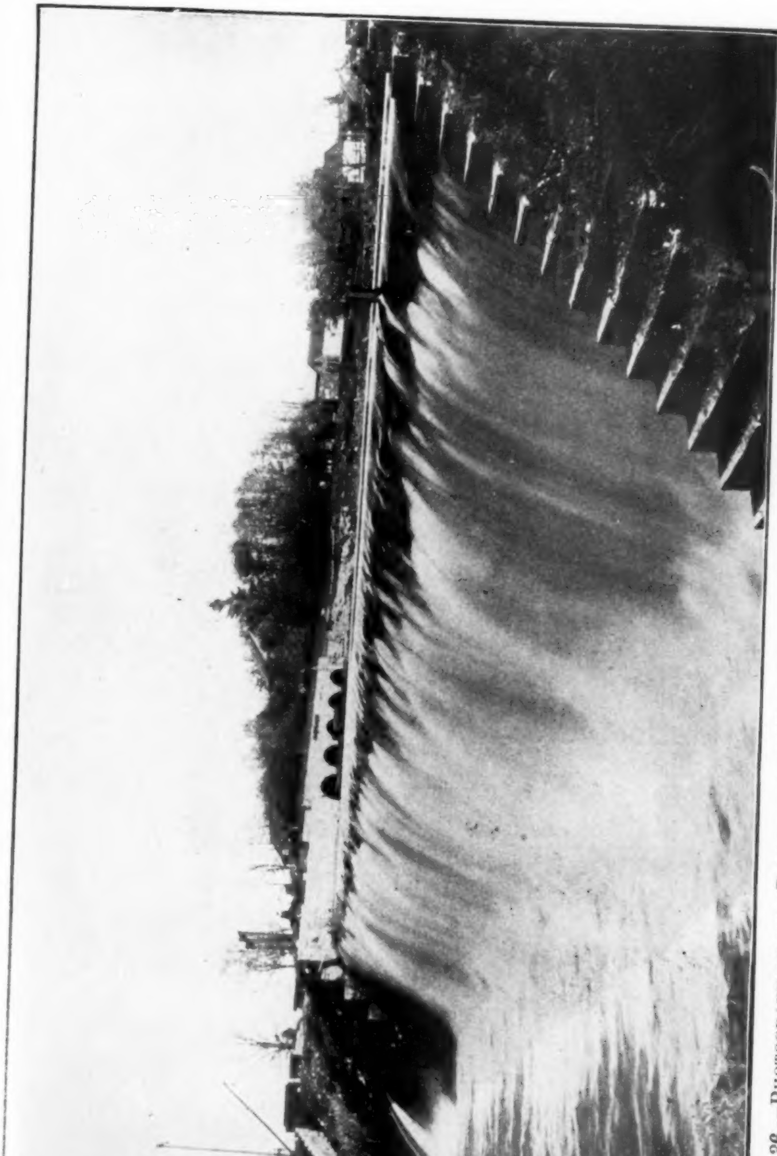


FIG. 36.—PHOTOGRAPH OF THE DAM WITH THE WATER ABOUT 3 FEET DEEP ON THE CREST. IN THE CENTRE OF THE PICTURE IS SEEN THE ARCH BRIDGE OVER THE ENTRANCE TO THE CANAL.

is direct-coupled a 350-kilowatt, 3-phase, 4,400-volt generator. Underneath the north end of this room is one of the 10-foot penstocks, in which there are three openings for receiving three wheels similar to the one above described. To each of two of these wheels will be connected two generators similar to those now connected with wheel No. 1, and the fourth will be provided with an extension shaft, to which will be belted an air compressor and other machinery.

14. The penstock pipes were built of steel $\frac{5}{16}$ inch and $\frac{3}{8}$ inch in thickness, specified to contain not more than $\frac{6}{100}$ of 1 per cent. of phosphorus, to have a tensile strength of from 52,000 to 62,000 pounds per square inch, 25 per cent. elongation, and 50 per cent. reduction. The plates were furnished—bent and punched—by the Variety Iron Works, of Cleveland, and Struthers, Wells & Co., of Warren, Pa., and erected in place by day labor.

15. The water wheel above mentioned consists of two American type runners on the same shaft, discharging outward. (The word "American" is used as referring to the general type of wheel, and not the particular wheel known by the trade name "American.") The wheel shaft stands at right angles with the penstock which enters the wheel case on the side. The flow of water through the wheel is regulated by guides connected to a cast-iron ring and moved by an eccentric. The water is discharged through quarter-turns and draft-tubes to the tailrace. The runners are built of gun metal bronze, so called, the movable guides of cast steel, the shaft of hammered iron, the case and draft-tubes of rolled steel, and the balance of the work of cast iron. The wheels were built by James Leffel & Co. under a contract in which the general form and dimensions, the kind and quality of materials, and the speed, power, and efficiency were specified. The speed is regulated by a Lombard governor geared directly to the gate rigging.

16. The two 350-kilowatt generators are connected to the wheel shaft by plate couplings having a movable plate between the faces. Both sides of this movable plate have a feather formed out of the same piece of metal and fitted to corresponding seats in the faces of the coupling. This enables the coupling to be driven with only two bolts, which can be quickly removed and the plate taken out in case it is desired to run either of the generators without the other. This wheel and generators run at

FIG. 37.—A TYPICAL PICTURE OF THE CANAL DURING CONSTRUCTION.

300 revolutions per minute. The two 350-kilowatt generators are of the revolving field type, having 24 poles and delivering three-phase current at a frequency of 60 periods per second and a pressure of 4,400 volts. Excitation is by two belted exciters each of sufficient capacity to supply both generators.

17. The switchboard of Vermont marble consists of two generator panels with indicating instruments, one exciter panel with switches and instruments for both exciters, two 4,400-volt feeder panels, with relay, circuit breakers, oil break switches, and watt-meters, one 220-volt panel with seven distributing switches, one transformer panel, and one 20,000-volt panel with three quick break switches having marble barriers.

18. The Hannawa Falls Water Power Co. owns the electric lighting plant in the village of Potsdam, four and one-half miles from the station. A double line has been built, each line consisting of three cables of seven strands each of No. 10 aluminum wire. This line was figured to transmit 375 kilowatts with a drop of 400 volts, delivering 4,000 volts at Potsdam. The 20,000-volt line is intended to run to the village of Canton, ten and one-half miles from the station, and thence to the city of Ogdensburg, nineteen miles farther. The 220-volt feeder panel was intended for station lighting and local distribution.

19. All of the lower floor of the power-house building not occupied by the electric station above described and all of the second floor will be occupied by a ground wood pulp mill of a capacity of 100 tons per day. Large quantities of spruce wood for the manufacture of pulp are still available in the region tributary to the Raquette River, and the location is within easy reach of the great pulp wood district of the Province of Quebec. For the purpose of shipping in wood and shipping out pulp, as well as for general purposes, the Hannawa Falls Water Power Co. has built a standard gauge railroad about four and one-half miles long, connecting with the New York Central at Potsdam. The mill has been arranged with a view to utilizing both the above-mentioned sources of wood supply. Wood from the Raquette watershed will be floated down the river and the power canal, taken out near the forebay, and carried by log conveyors to the piling ground and sawing and barking buildings on the flat ground to the north of, and about 40 feet below, the forebay. After being sawed and barked it will be taken on narrow-gauge cars, hauled by a small electric locomotive, to the grind-

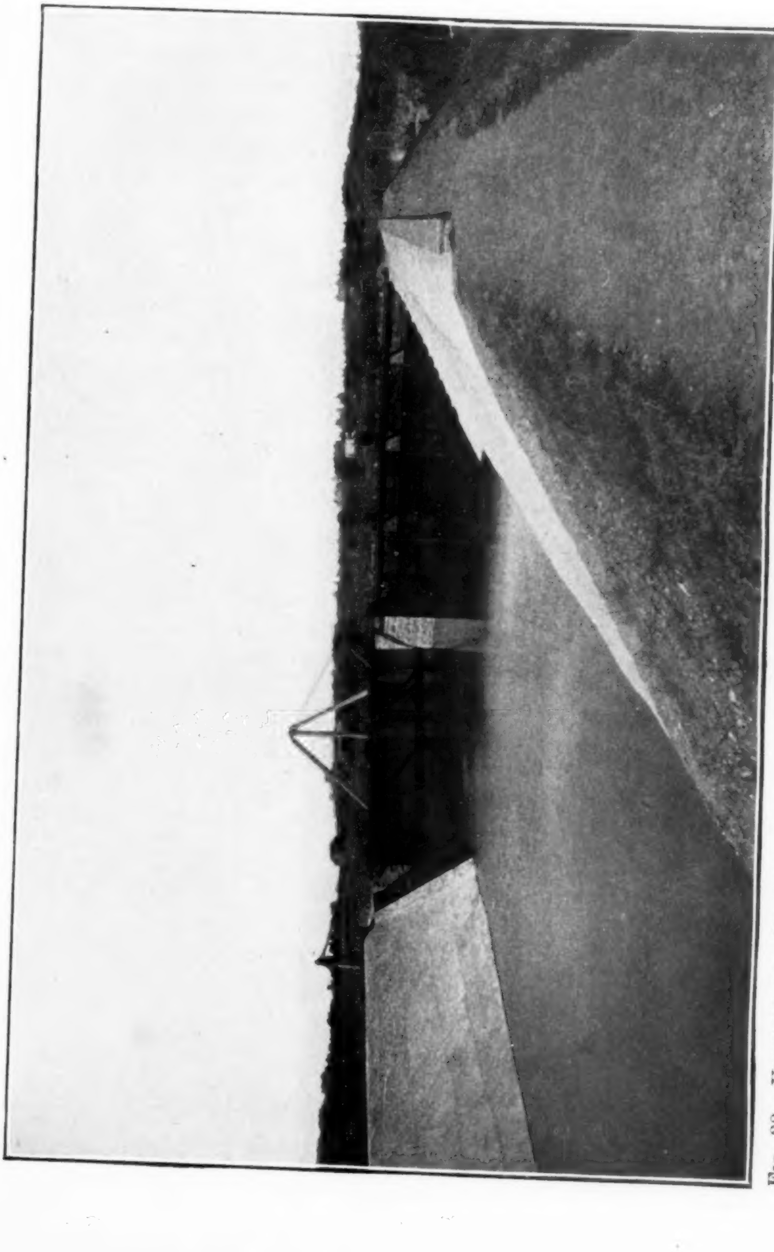


FIG. 38.—VIEW OF THE FOREBAY WITH THE CANAL FILLED. THE CONCRETE COVERING ON THE EARTH BANKS IS PLAINLY SEEN.

ing room. The Canadian wood will be delivered, peeled, on railroad cars and unloaded either in the storehouse located 232 feet from the power house or in the grinder room, to which the railroad track is extended. The stored wood is brought to the grinder room by means of cars on the same track.

20. In the grinder room are placed two pairs of water wheels of 3,500 horse-power capacity each, on horizontal shafts, supplied with water from two independent 10-foot penstocks and discharging into a common tailrace. The grinders are of the four-pocket type, with stones 54 by 27 inches, twelve in number, three on each side of each wheel, direct-coupled to the same. The foundations for the grinders are of masonry firmly built, and under each grinder is a ditch faced with large, smooth stones to receive the ground stock. The front ends of the ditches are closed and provided with a drain hole in the bottom for occasional cleaning. The back end is open and has a groove cut on each side to receive the dam. From these ditches the stock flows over the dam into a wooden hopper and through the floor to a wooden spout, which conveys the stock to a large automatically cleaned screen located directly over the stock tank in the basement. Two centrifugal stock pumps, placed on a level lower than that of stock in the tank, convey the stock further through a spiral riveted pipe to a tank built on four masonry piers on the bank between the power house and the forebay. These two pumps usually work together, but in case of failure of one of them, either pump can be shut down and repaired while the other is capable of doing the work alone for a short period. From the above-mentioned tank, the stock is conveyed by gravity to the screens in the wet-machine room. This room is located above the grinder room and occupies the entire length and width of the building. The screens are placed near the walls and driven from two countershafts on each side of the room. Space is provided for forty-eight 12-plate screens, placed in two rows, one higher than the other. They are coupled together in groups of six, each group driven by a separate pulley There is room enough also for twenty wet machines provided with hydraulic pressure on the rolls and placed toward the centre of the building with the press ends facing each other. The upper row of screens receives the stock, as above described, from the stock tank on the bank through a spiral rivetted pipe running in the trusses above the screens, and each screen is

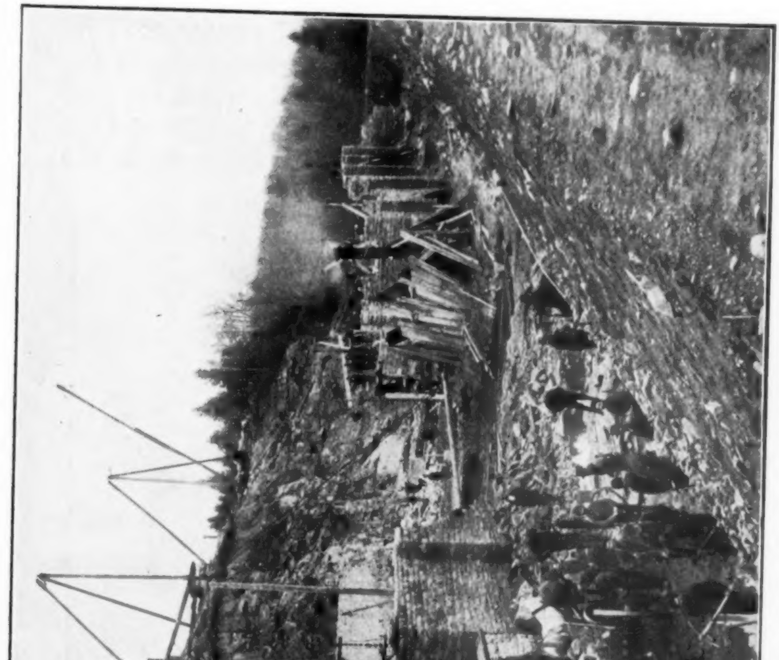


Fig. 39.—Photograph of the Power House during Construction, showing the Beginning of the Tailrace and the Foundations of Power House.

supplied with stock independent of the other. The upper screens discharge into a common wooden trough, and this trough, in its turn, supplies the lower row of screens, each independently of the other. The lower row of screens again discharges into another common wooden trough, which supplies the wet machines. By means of these common troughs and the independent supply on the screens, any disturbance in the

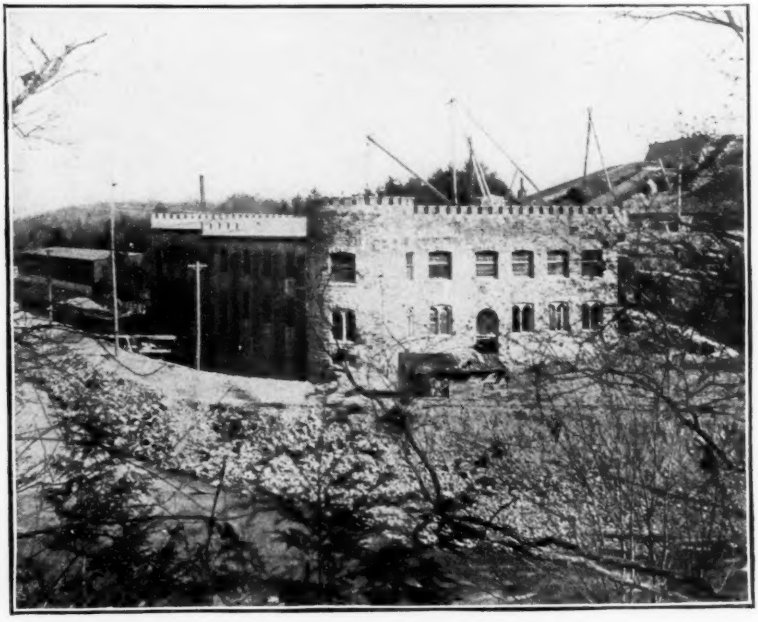


FIG. 40.—VIEW OF THE POWER HOUSE FROM THE UP-STREAM END. THE WOODEN STOREHOUSE SEEN IN THE BACKGROUND; ALSO THE FOREBAY AND THE PENSTOCKS UNDER CONSTRUCTION AT THE RIGHT OF THE POWER HOUSE.

capacity of either a screen or a wet machine can be repaired at any time without decreasing the output seriously. All screens are provided with independent power-driven rakes. When the pulp is taken from the wet-machine rolls and folded it is laid on a conveyor running between the two rows of wet machines.

21. The return water from the wet machines is discharged under the lower row of screens, and conveyed to a tank located outside of the building, on a level between the first and second floors. From this tank the most of the return water is delivered

to the grinders by gravity, though some of it is pumped back to the screens with a centrifugal pump placed by the side of the two stock pumps in the basement. The draining of the floor in the wet-machine room is done through holes in the floor, one under the wet machines and one between them, connected to pipes running under the floor along the building. All tanks, screens, and wooden troughs are provided with overflow, conveying the stock back to the tank in the basement.

FIG. 41.—THE TAILRACE UNDER CONSTRUCTION. IN THE CENTRE OF THE PICTURE IS THE MADE EMBANKMENT, SEPARATING THE TAILRACE FROM THE RIVER. A DRY WALL HAS SINCE BEEN BUILT ON BOTH SIDES OF THE TAILRACE, AS SHOWN ON THIS PICTURE ON ONE SIDE.

22. The power for the wet-machine room is delivered by means of a rope drive from water wheel No. 4 in the electric station to a main shaft running the full length of the wet-machine room in the centre of the building and supported by hangers bolted to a steel frame connected to the trusses. Strained fresh water for shower pipes and hose is supplied by two pumps coupled together and placed in the wet-machine room. At the same place, and driven from the same shaft as the fresh water pumps, is a suction pump for producing vacuum in the suction boxes on the wet machines. Another rope drive furnishes the power from the main shaft to the pumps; one branch of the

drive runs down to a countershaft in the basement for the stock pump and the return water pump, and another branch to the countershaft for the fresh water and suction pumps.

23. The conveyor between the wet machines consists of 125 small cars fastened to a moving endless steel cable, and runs the whole length of the wet-machine room, with the driving mechanism in the far end of the room. From this room it runs on an incline on wooden trusses supported by wooden bents, to the storehouse (Fig. 42), and through the entire length of this building. The cars are carried back reversed on a lower track. When the pulp-laps reach the storehouse, they are either loaded on railroad cars placed at the side of the conveyor, or stored, which can be done to a capacity of 3,000 tons.

24. The entire plant has been designed by, and built under the personal supervision of, the writer. The details of the pulp mill have been worked out by Mr. Louis DeGeer, and the exterior of the power house is the design of Mr. V. Emile Thebaud, architect. All the excavation and masonry have been done by the faithful sons of Italy, under the direction of my assistant, Mr. Wilson Gilman, and foreman Louis La Barge. Mr. O. H. Tappan, secretary and treasurer of the company, has given the closest personal attention to the management of the work, and Mr. Wm. B. Cogswell, member of this Society, and a director of the Hannawa Falls Water Power Co., has frequently visited the work, and has made many valuable suggestions.

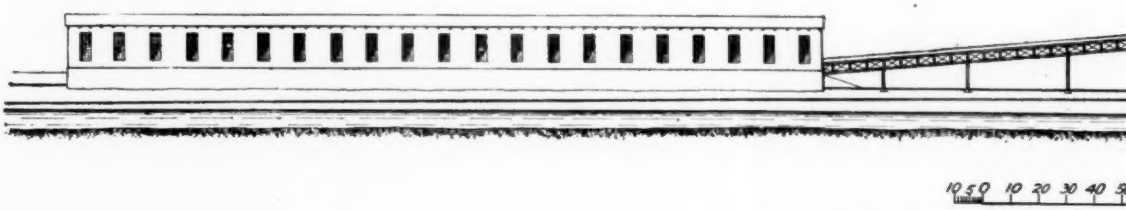
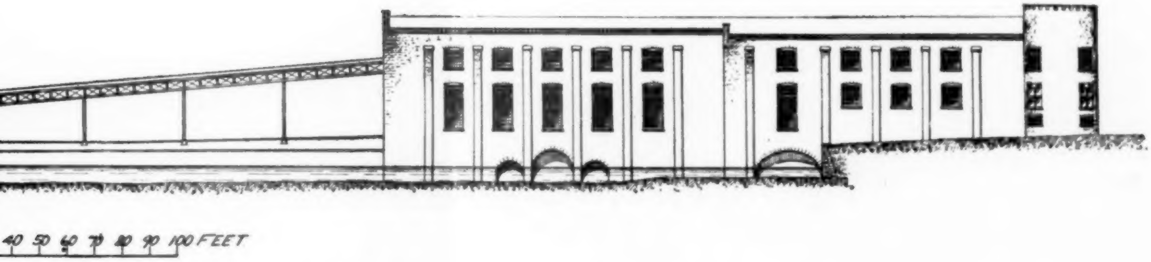


FIG. 42.—ELEVATION OF POWER HOUSE

WALLACE C. JOHNSON.



OUSE, STOREHOUSE, AND PULP CONVEYOR.

No. 920.*

A NEW VALVE GEAR FOR GAS, STEAM, AND AIR ENGINES.†

BY ERNEST W. NAYLOR, PHILADELPHIA, PA.

(Member of the Society.)

1. So far as sharp cut-off, expansion, exhaust, and compression were concerned, the early engines with hand-actuated valve gear were better than any engine with valve gear actuated by mechanical means at the present day; but the speed being limited by the endurance of man, necessity for continuous work and more speed brought into use mechanically actuated valves more or less perfect. High steam pressures made it necessary to compound the cylinders in order to get the most possible out of the steam; but even with the vast improvements made in recent years, the engine is still limited in speed by its valve gear; expansion and compression are also limited in single

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* Presented at the New York meeting (December, 1901) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For further discussions on this topic consult *Transactions* as follows:

No. 31, vol. ii., p. 122: "A Brief Treatise on the Steamboat Cam." Lewis Johnson.

No. 77, vol. iii: "Spring Face for Poppet Valves." Gram Curtis. (*See American Machinist*, June 3, 1882.)

No. 97, vol. iii., p. 150: "Back Pressure on Valves." S. W. Robinson.

No. 116, vol. iv., p. 268: "Balanced Valves." C. C. Collins.

No. 130, vol. v., p. 34: "Motion Curves of Cut-off Valves." A. Wells Robinson.

No. 335, vol. x., p. 521: "Cornish or Double-beat Pump Valves." A. F. Nagle.

No. 567, vol. xv., p. 177: "The Buckeye Engine Valve Gear." A. K. Mansfield.

No. 616, vol. xvi., p. 117: "Description of a Cam for Actuating the Valves of High-speed Steam Engines." Charles T. Porter.

No. 617, vol. xvi., p. 134: "Description of an Improved Centrifugal Governor and Valve." Charles T. Porter.

No. 769, vol. xix., p. 449: "The Stevens Valve Gear for Marine Engines." Andrew Fletcher.

No. 793, vol. xx., p. 42: "Valve Gear of the Willans Engine." John Svenson.

No. 809, vol. xx., p. 475: "The Allen Valve for Locomotives." C. H. Quereau.

No. 824, vol xx., p. 967: "New System of Valves for Steam Engines, Air Engines, and Compressors." F. W. Gordon.

cylinder engines to a considerable degree; and while we get increased economy by compounding, the extra cost of the engine is a serious item to many users, and they prefer to buy a cheaper engine and use more coal.

2. The writer has for many years made this question a special study and, in presenting this paper before the Society, thinks he can show marked economy from the use of the valve gear here described, a gear whereby perfect expansion and compression can be obtained in simple engines using pressures up to 200 pounds per square inch, having a range of cut-off from 0 to 100 per cent. of the stroke, and the same range in exhaust and compression, giving ability to stop or reverse from any part of the building or engine-room without shutting off steam. This gear will also admit steam many times during the same stroke, and ability to stop in a very short space of time without shock or jar is another advantage, while the speed is only limited by the possible piston speed.

The engine that has been under test for twelve months is small, but the results are certainly remarkable. It was calculated for a 5 horse-power, single-acting, 3-cylinder engine with 150 pounds per square-inch boiler pressure, and to run at 500 revolutions per minute, and has been run at varying pressures from 1 to 60 pounds per square inch; it was not possible to reach a higher pressure where the tests have been conducted; the engine has also been successfully run with compressed air.

3. The cylinders are $2\frac{1}{2}$ inches diameter by 4 inches stroke; the clearance is *one per cent.* of the cylinder capacity. Poppet valves placed in the heads are used both for steam and exhaust, the maximum opening being $\frac{1}{25}$ the area of the cylinder in each case. Table I. gives a few results out of the many tests we have made. The engine has run thirty million revolutions up to the date of writing this paper (September, 1901), and not a single bushing has been taken up or valve refaced. There are no glands, so that no packing has been used, and no piston rings were used, the pistons being very deep and grooved. The cylinders were well covered, but pipes, valve bodies, and boiler were uncovered; under these conditions the exhaust was very dry even when using as high rates of cut-off as shown in the table.

4. Figs. 43-48 show the gear as applied to two Westinghouse engines; one being 9 by 8 inches, and the other compound, 8 and 13 inches by 8 inches. These engines have not been tested at the

date of writing, but the design being the result of the tests on the engine used, it is thought better to use them as an illustration of the working of the gear.

TABLE I.

No. of test	1	5	20	28	50	60	60 A
Load	None.	None.	None.	None.	$2\frac{1}{2}$ h.-p.	3 h.-p.	None.
Lead	1%	2%	2%	2%	3%	3%	2%
Cut-off at per cent. of stroke	50%	15%	10%	8%	3%	2%	Dead centre
Exhaust open at per cent. of stroke	85%	85%	85%	90%	85%	80%	85%
Exhaust closed at per cent. of stroke	50%	20%	15%	20%	15%	10%	Dead centre
Area of steam-valve opening	$\frac{1}{125}$	$\frac{1}{125}$	$\frac{1}{125}$	$\frac{1}{125}$	$\frac{1}{125}$	$\frac{1}{125}$	$\frac{1}{125}$
Area of exhaust-valve opening	$\frac{1}{6}$	$\frac{1}{60}$	$\frac{1}{60}$	$\frac{1}{60}$	$\frac{1}{60}$	$\frac{1}{60}$	$\frac{1}{60}$
Steam pressure in pounds per square inch	1	5	20	28	50	70	70
Revolutions per minute	60	300	440	600	540	680	875

The lettering refers to the parts as follows :

AA' cylinders, BB' steam valves, CC' relief valves in steam valves, DD' exhaust valves, EE' electromagnets controlling steam valves, FF' electromagnets controlling exhaust valves, G to G^4 armatures and levers connected to valve spindles, the travel of which is adjustable for a range from 0 to maximum by bolts and nuts H to H^4.

I and J are contact disc controllers, which control the time of opening of the steam and exhaust valves and the point of stroke of the piston at which the valves are closed, or, in other words, the lap, the lead, exhaust opening and closing, expansion and compression.

KK' are adjustable levers carrying brushes, or contact points, to make electrical connection between the sickle-shaped contact plates and the magnets controlling the steam valves ; LL' are levers for exhaust valves similar in all respects to KK'.

MM' are lever arms carrying the contact levers KK' and LL'. The bosses or hubs of these levers are extended up to the bracket N, which carries all of the adjustments and contact levers. The contact levers KK' and LL' can be placed in any position in relation to the position of the cranks by turning the hand wheels OO' which actuate the worms and worm wheels P to P', the wheels being keyed to the hubs of MM', so that

either positive or negative lead may be given the steam valves while the engine is running; in a similar manner the time of opening of the exhaust valves in relation to the position

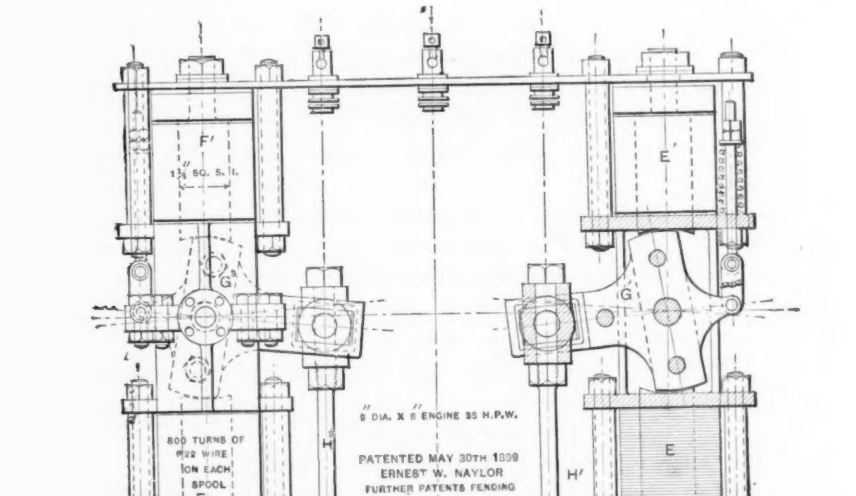

FIG. 43.

of the piston may be adjusted. The adjusting nuts Q^1 to Q^4 are used to vary the relative leads of high and low pressure cylinders and the points of exhaust opening.

5. The discs RR' are merely to carry the binding screws for

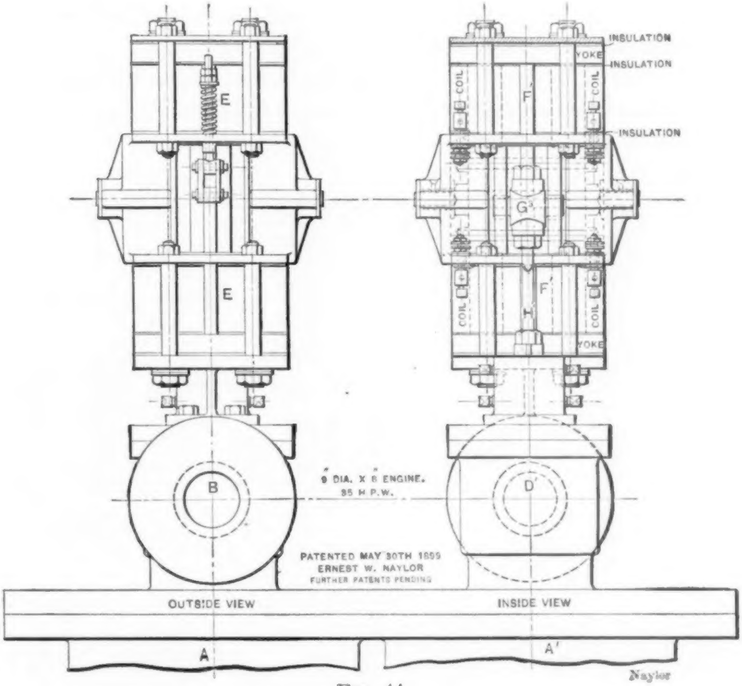
INSULATION
YOKE
INSULATION
COIL
F
E
INSULATION
G
E
F
H
YOKE
B
D'
9" DIA. X 8" ENGINE.
35 H.P.W.
PATENTED MAY 30TH 1899
ERNEST W. NAYLOR
FURTHER PATENTS PENDING
OUTSIDE VIEW
INSIDE VIEW
A
A'
Naylor

FIG. 44.

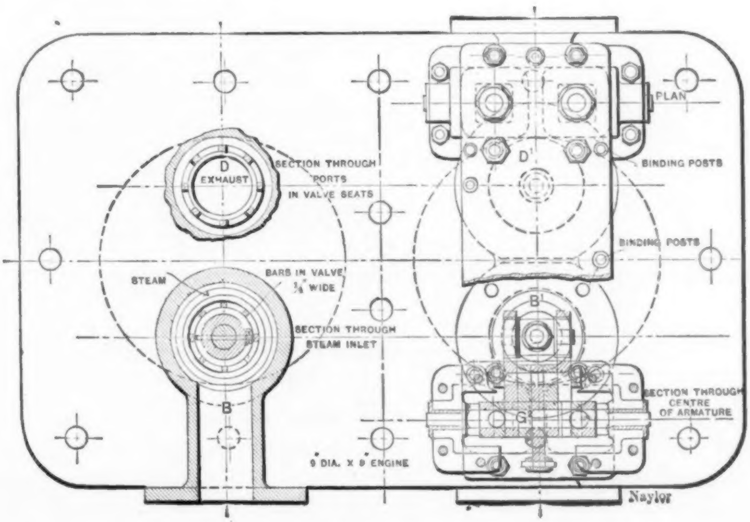
PLAN
D
EXHAUST
SECTION THROUGH PORTS IN VALVE SEATS
D'
BINDING POSTS
BINDING POSTS
STEAM
BARS IN VALVE 3/8" WIDE
SECTION THROUGH STEAM INLET
B'
B
SECTION THROUGH CENTRE OF ARMATURE
G
9" DIA. X 9" ENGINE
Naylor

FIG. 45.

the wiring to the several magnets, and to keep electrical connection whenever the levers MM' are turned.

The levers SS' are keyed to the sleeves ss', which connect by links and levers to the contact levers KK' and LL', the levers SS' being also connected to the governors TT', which respec-

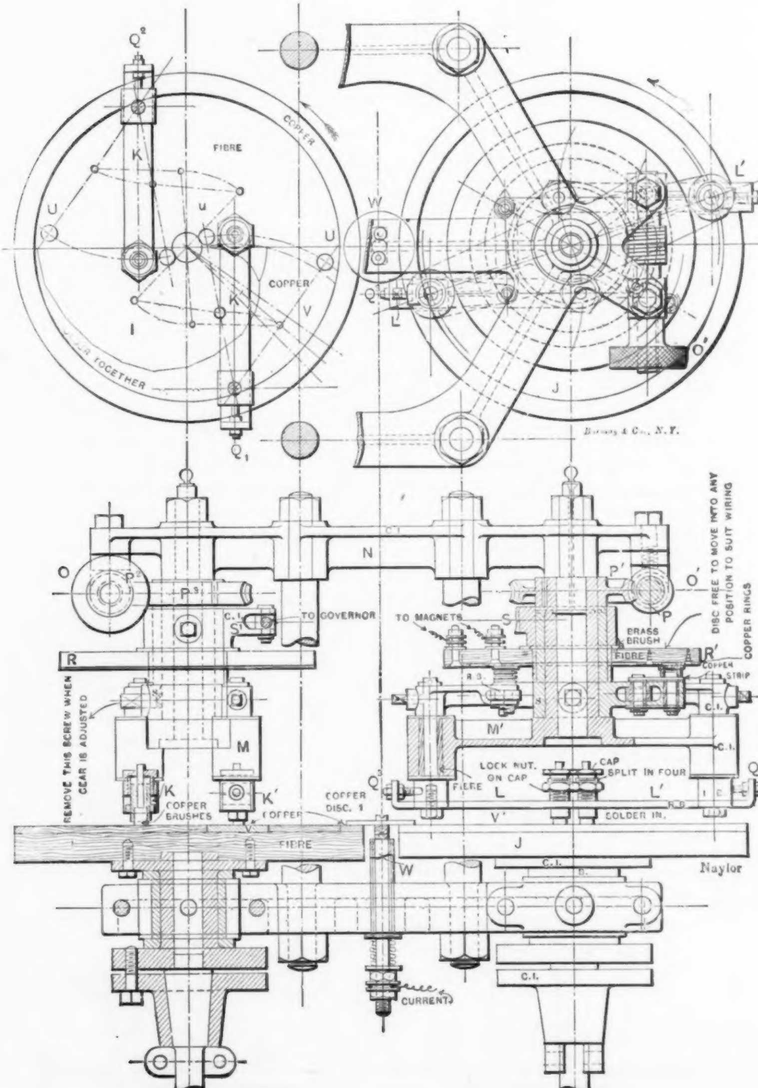

FIG. 46.

tively control the steam and exhaust valves. In marine, automobile, and locomotive engines the governors are dispensed with and starting levers used instead.

The range of the levers KK' and LL' being u to U, it will be

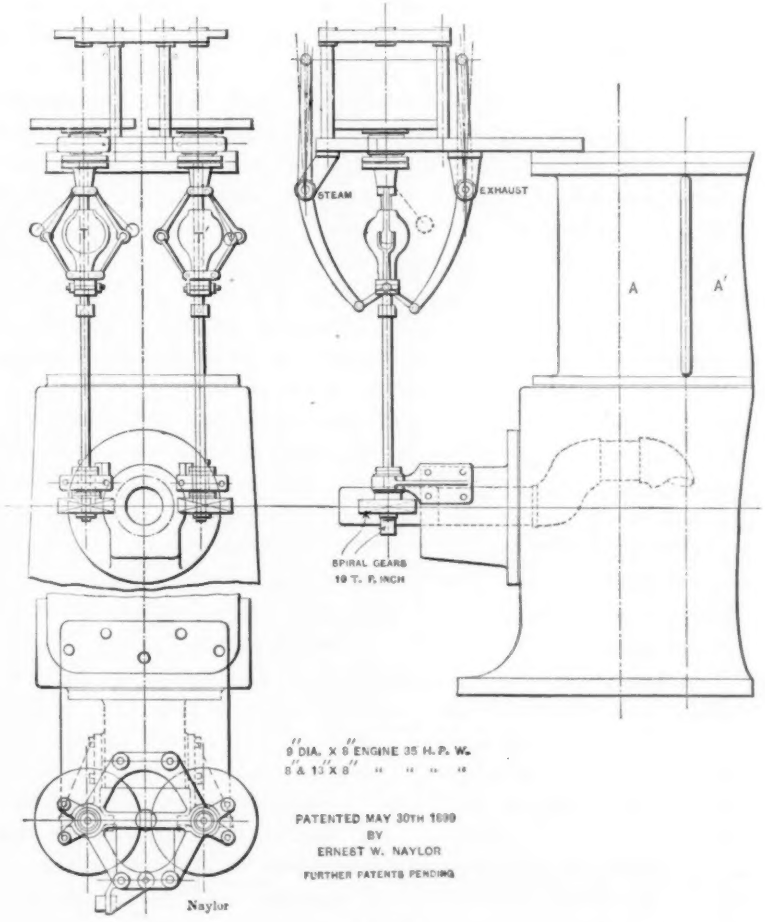

FIG. 47.

seen that valves may be held open from 0 to 100 per cent. of the stroke or to any intermediate position, according to the length of time contact is made with the plates VV', the current being passed to these plates through the connection W, which is connected to one electrode, the other ends of the magnet coils

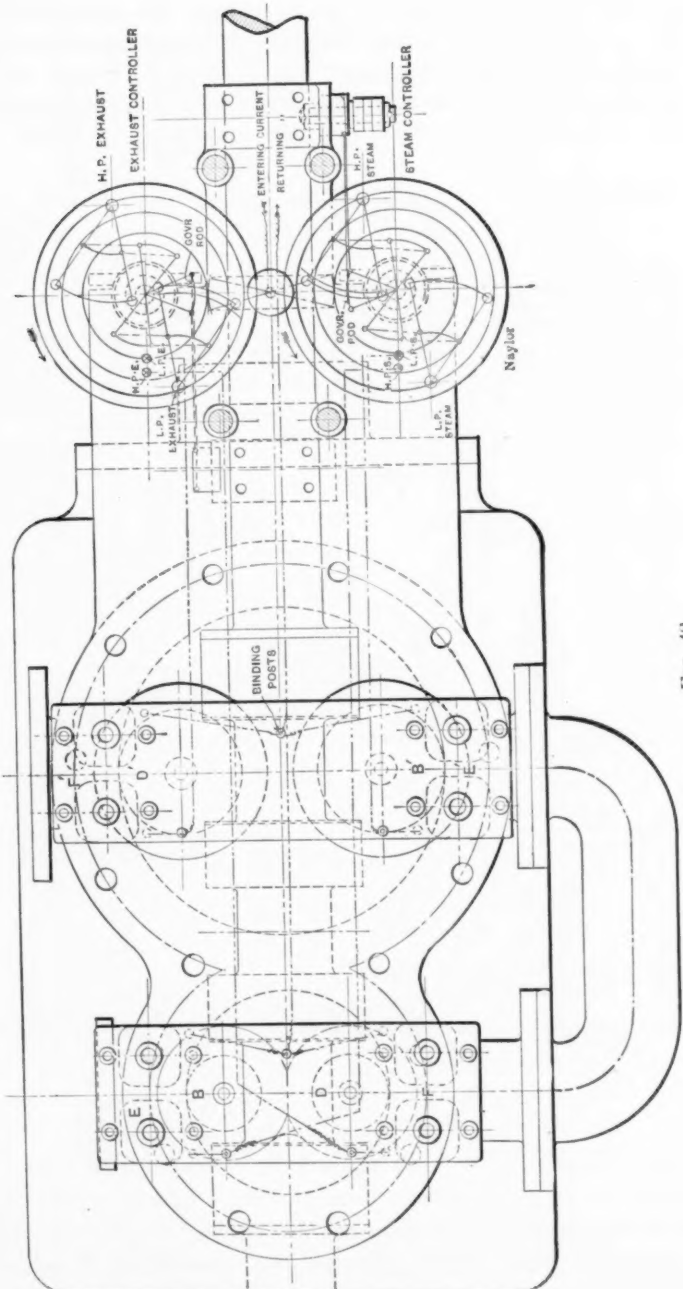
H. P. EXHAUST
EXHAUST CONTROLLER
ENTERING CURRENT
RETURNING
H.P. STEAM
STEAM CONTROLLER
GOVR ROD
GOVR. ROD
L.P. EXHAUST
L.P. STEAM
Naylor
BINDING POSTS
D
B
E
F

Fig. 48.

all being connected to the other electrode, as shown on Fig. 48. From the above it will be seen that the valves may instantly open and close, and steam be given many times during the same stroke.

6. All eccentrics, rods, levers, links, and other usual valve gear being done away with, the new valves and valve gear are placed on the heads, so that erection is easy. Clearance can be gotten down to one-tenth of one per cent. in large cylinders, being only one per cent. in a $2\frac{1}{2}$ by 4 inch cylinder, as previously mentioned; therefore compression up to initial pressure is easily obtained without any appreciable loss of efficiency. The valve gear may be placed in any position most suitable to the design of the engine, regardless of the position of the crank shaft; the friction of the gear is a negligible quantity, and adjustments may be made while the engine is running. During the tests, a piece of newspaper placed between the armature and poles of the magnets (reciprocating magnets were used in this test) made a difference of from 75 to 100 revolutions per minute.

7. The valves are all $\frac{1}{2}$-inch diameter, and, as shown in the table, the lifts were for the steam valve $\frac{2}{100}$ of an inch, and for the exhaust valves $\frac{4}{100}$. The exhaust could not be heard two yards away and had not enough energy to blow the ash off a cigar. No particular care was taken in the manufacture of the engine; but if properly adjusted for the load, it was impossible to make it "run away" though the load was suddenly taken off, when running at full speed and without the use of a governor. The larger the engine, the smaller the relative cost and size of the gear, the drawings here shown being amply large for one of 500 horse-power. There was no vibration; when a glass of water was placed on the cylinder head and the engine stopped *at once*, not the slightest disturbance of the water was evident.

8. It will readily be seen that, when using compressed air as a driving power, the economy is very much greater than with any other valve gear; and it is possible, when motors are to be used in various scattered buildings, that air can be used much more economically than steam, owing to the absence of condensation in transmission and the high rate of expansion obtainable.

9. In the case of gas engines, the best burning or explosive mixture is readily obtainable, as the proportion of air to gas can

be at once adjusted; likewise the cut-off is adjustable, therefore any amount of mixture can be admitted to the cylinders, thus making regulation easy of accomplishment; the exhaust is also adjustable from 0 to 100 per cent.

Since writing the description of a "new valve gear," the loss of two British "destroyers" has brought to my memory many more facts and observations regarding vibration in engines. It has always been a fad or fancy with engineers and inventors that a rotary engine is non-vibratory, owing to the presumed perfect balance of the rotating parts. Such a belief is fallacious, as I believe Laval acknowledges that the shaft in his motor assumes a curve thus , which is a cause of unbalance; the centrifugal action due to such a curve is enormous, and causes a sympathetic vibration which it is impossible to counteract. Recent reports of the action of Parsons' steam turbine as applied to vessels bear out this statement, as it is admitted that the vibration astern is so violent that it is impossible for even seamen to stand it for any length of time.

No doubt many of you have noticed the vibrations set up by the simple electric fans used in offices all over the country. When many are in use in a large, open office, it sometimes occurs that two or more get into sympathetic action, and then even the floor vibrates. I have many times had to remove such a fan from the top of my desk, as it was impossible to write a letter, owing to the vibration.

It must be certain that when the horse-power is increased to thousands, the vibration is increased proportionately and must have an enormous effect on any vessel; and where two or more such steam turbines are in close proximity, as in a "destroyer," the effect must be disastrous. Another cause of the failure of these vessels is, in my opinion, the weakness of the deck structure, owing to the large hatchways necessary to admit the boilers and engines; shear of deck line is also weak construction. There ought to be curvature from the water line when the vessel is on the stocks, and then it would have resistance when water borne; an example of such construction on a small scale is known of old to all builders of racing skiffs, especially on the Tyne, where these turbine destroyers were built. No old builder there would build a racing skiff without giving a large reverse curvature, their contention being that, since the weight of the man is all in the centre, and the bow and stern are of less displacement than the midship

section, when the man seats, the boat will "breathe," or assume a straight line on the water, as there is no keel on such boats, and all the sections are outward curves in order that the resistance of the skin surface may be reduced to a minimum, and the weight-carrying capacity be a maximum. The theory is perfectly correct, although I do not suppose theory ever entered into the heads of those old Tyne boat builders; the fact that boats broke their backs in rough water suggesting the idea of giving this reverse curvature.

In the case of the destroyers and the Turbinia, the great speed of the turbines, and consequently the enormous aëration of the water astern, caused the after part of the vessels to have less bearing capacity or buoyancy, therefore the bow lifted clear of the water, making a cantilever of the vessel, with the fulcrum in the centre and the forward part of the vessel totally unsupported by the water; hence it is easily seen how they broke their backs—or rather it ought to be called "chests"—as the decks gave way first.

It is an old trick with so-called strong men to carry heavy stones on their chests and have them broken there by sledge hammers; but if it were not for the curvature of the spine, the men would inevitably be killed, not only by the weight, but also by the blow. Such is the case with these "destroyers;" they lack curvature, and have in addition the great vibration of the steam turbine on the backbone, or keel, without the advantage given by the man's ribs curved up from his backbone. In addition to this the lifting of bow and consequent pounding of the water amidship tends to crush in the hull, hence a double strain is set up, and, of course, accentuated by the vibration of the turbines.

The above remarks may at first glance appear foreign to the subject in hand, but if you study them well you will see the point I endeavor to make, which is, to build an engine which is without vibration at high speed, and is the ideal marine engine.

I hope in the near future to make a test of an engine, with valve gear as above described, suspended by cables from the roof or floor of a building, and note the vibration or oscillatory movement. Such a test would prove the self-contained properties of the engine, and also show any possible vibratory or pendulous action of the engine.

DISCUSSION.

Mr. J. H. Barr.—Mr. President, I regret that the writer of this paper did not give us some more detailed information as to his steam distribution and other points. The steam distribution, judging from his table, must be very peculiar. In the tests, as per Table I., the initial pressure is given at from 1 to 70 pounds in different runs. The first test was, I believe, at one pound initial pressure, cut off at 50 per cent., and compression at 50 per cent. stroke, which would correspond to a very odd indicator diagram, particularly with an engine having only "1 per cent. lead and small clearance." The fact that the exhaust could not be heard two yards from the engine does not seem so astonishing when steam is cut off at 50 per cent. stroke, and the initial pressure is only one pound above atmospheric pressure. That the exhaust does not blow off the ashes from a cigar is not remarkable; it might suck the ashes from a cigar, however, if the cigar were near enough to the end of the exhaust pipe.

The distribution which he gets is certainly very peculiar; so much so, that I think he should have accompanied his paper with some diagrams giving us an idea of what he accomplishes. The reduced time required to open and to close the valves seems to be the principal feature of this gear.

I have had some difficulty in making out what Mr. Naylor strives to get with this engine. The fact that the valve is closed sharply does not seem to be sufficient justification for a claim that the cylinder condensation is diminished. The small clearance with the poppet valves would, of course, to a great extent, reduce the surface exposed, and therefore tend to cut down the cylinder condensation.

I regret very much that we have not more evidence to indicate what this engine is really supposed to accomplish. It seems to me that the paper is very incomplete in essential particulars.

Having commented somewhat unfavorably on this paper at the time of its presentation, after only a hasty reading, I considered it incumbent upon me to read it again carefully. The result of this further effort is a confirmation of my previous opinion that the paper should be supplemented by pertinent data on many points before it appears in the *Transactions.*

Aside from the description of the valve mechanism, I am able

to make very little of it. I will, however, confine my present remarks to two or three features.

The writer, "in presenting this paper before the Society, thinks he can show marked economy from the use of this valve gear." I fail to find in the paper even the slightest evidence for or against the economy.

The statement in paragraph 2, that this gear will "admit steam many times during the same stroke" has puzzled me considerably. Granting the possibility, what beneficial result is accomplished by the feat?

The more I study Table I., the more I am confused. If this table accurately represents the conditions of tests, I cannot understand why the engine ran at all.

I hope that Mr. Naylor will elucidate these and other points before the final publication of the paper.

*Mr. Ernest W. Naylor.**—Before replying to Mr. H. H. Suplee and Professor John H. Barr, I wish to say that I am sorry that I was unable to attend the meeting and read the paper, so that I might there answer all criticism. The objections raised are also a disappointment to me, as they are, in my opinion, the ones most easily answered. I fully expected that the greater part of the discussion would have been upon the small relative area of ports to cylinder area.

I may also state that the Secretary called my attention to the incompleteness of the paper, but, unfortunately, I could not possibly revise the paper in time for the meeting; and as I fully expected to be at the meeting, I trusted to more fully explain and demonstrate the action of this valve gear at that time, after such members as cared to had seen the engine running under brake load.

A point to which I would call attention is the effect of compression in reducing the cylinder condensation; this being so high and the revolutions per minute so great (8.33 per second taking 500 revolutions per minute as an average), the steam enters a very hot cylinder, and the head has little time for radiation of enough heat to produce condensation.

Still another circumstance points to very small cylinder condensation, which is the small valve opening; the valve opening being at its maximum $\frac{1}{25}$ of the area of the cylinder cross-section,

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* Author's closure, under the Rules.

and the actual opening being only $\frac{1}{125}$ of that area, and no larger being possible when so set, if there had been condensation to even what would be considered in general practice a negligible amount, it would certainly have made itself *heard* and most probably *felt*.

In reply to Professor Barr's criticism, I would have been glad to give more detailed information regarding the steam distribution; but, under the circumstances, I do not see that it is possible to give more than is contained in Table I., except that the tests might be continued indefinitely.

An indicator with a cylinder ½-inch diameter and 1-inch stroke would take as much steam as the clearance space, without taking into consideration the connections, which would take as much more, even if the indicator were screwed direct into the head. Again, at such speeds and short stroke, I have yet to become acquainted with the indicator which will indicate within 50 per cent. of the actual steam consumption or distribution.

As to steam consumption per brake horse-power per hour, it was my intention to have made sufficient tests at Columbia University to determine this, using a surface condenser *without vacuum* for this purpose; but we never had a run long enough to produce any water from the air pump before we had a breakdown, owing to excessive water in the steam pipes of the testing laboratory. I may even say that the extension shafts carrying the valve gear were purposely pinned to the couplings in such manner that the pins would shear under such conditions before the engine could be wrecked, the momentum of the fly-wheel being sufficient to do this when the engine was instantly stalled by water. I had new and larger pins fitted, and reset the valves on Tuesday, December 3d, when I was unfortunately taken ill and had to leave for home, expecting to return in time to present the paper.

No doubt, from a casual reading of the table, the steam distribution may appear peculiar; but in this relation two circumstances must be taken into consideration—that is, leakage past the pistons and *possible* lag of the magnets, although close observation fails to detect any such lag, and the bottom of the cylinders being open to the atmosphere, any undue leak of steam would at once have been seen; with 100 pounds pressure no leak of any consequence is observable.

In relation to the cigar-ash question, I did not try it when running without load at 1 pound, but only when running under load

at higher pressures, the run with 1 pound being merely to demonstrate the small friction of the engine.

The results were much the same, so far as noise of exhaust was concerned, when using 100 pounds pressure and exhausting into the laboratory pipes one foot away from the engine, the only difference being that both cylinders exhausted into one 1-inch pipe.

The question of diagrams is answered above; but, to pursue the matter, I have under construction an apparatus which I expect will show on a suitable chart the points of steam-valve opening and closing, also the points of exhaust-valve opening and closing, in relation to the position of the crank, so that from these data a diagram may be constructed (and compared with an indicator diagram from larger engines) which will be more reliable than an indicator diagram taken from such a small engine.

The reduced time to close the valve is certainly one (Mr. Barr says the principal) feature; but the instant *full* opening of the valve is of far more importance, and has also been a "Waterloo" to many engineers, as no gear, to my knowledge, has so far been constructed which could be made strong enough to stand the strain at any speed above 20 revolutions per minute.

Not only this, the mere fact of having a gear which will instantly open the valve wide *is the secret of the very small valve opening area as compared to the area of the cylinders.* This *fact* is easily demonstrated in the engine under review, as follows: In that engine, $\frac{1}{125}$ of the area of the cylinder was found to be the best for the pressure and speed desired. Upon increasing the opening $\frac{1}{500}$ of an inch, a difference of behavior is observable; on doubling the opening, the engine slows down 50 per cent., and upon still further increasing the opening, the engine *will not run at all.* Much more liberty may be taken with the exhaust valves without any great change in the behavior of the engine.

In regard to Professor Barr's statement that the reduced clearance exposes less surface for condensation, this has little or no effect, and does not appreciably reduce that surface, as the following figures show: The cylinder is $2\frac{1}{2}$ inches diameter, hence the area of the head and piston is 9.8 square inches. Since the clearance distance between piston and head is less than $\frac{1}{32}$ inch, the surface exposed on the cylinder is .23562 square inch; if the clearance between head and piston be made $\frac{1}{2}$ inch instead of $\frac{1}{32}$ inch, this would only make the cylinder area exposed 3.92 square

inches, or less than one half of the area of the piston and cylinder head together, and no engineer would give ½-inch clearance in a large engine at the present time. It is of vastly more importance to have heads well protected and to reduce clearance to a minimum, in order to get compression up to initial pressure, or above if possible, so that the cylinder head and piston are at least as hot as the entering steam. In this valve-gear it is quite possible to obtain that result, as, if the compression exceeds the initial pressure, it lifts the steam-valve automatically and there is little or no loss in the efficiency of the engine.

As to what the engine is supposed to accomplish, as Professor Barr says, the paper does not give much evidence, but paragraphs 6, 7, 8, and 9 give a few of the *claims*; the *evidence* I had, as before stated, hoped to demonstrate before the members. I repeat here that the engine has accomplished everything claimed, and more, and I trust I will have the opportunity to demonstrate to the satisfaction of Professor Barr and other members that it is so.

Answering Profesor Barr's further comments, I would say that increase of economy is claimed for the following reasons:

First.—Reduced clearance, thereby saving steam.

Second.—Cut-off at any point of the stroke, hence more perfect expansion in one cylinder without the necessity of compounding to save cylinder condensation, the small clearance being here again a great advantage.

Third.—Higher speeds without danger to the valve gear, thus lessening condensation.

Fourth.—Smaller valves and lighter gear generally: reduced first cost and cost of repairs.

Fifth.—Superheated steam may be used without fear of packings burning out, as rings are used in large engines and none in small engines.

Sixth.—Absence of vibration, therefore longer life of the engine.

Seventh.—Lubrication of pistons without the lubricant coming into direct contact with the steam, or using it as a vehicle to convey the oil to the piston; this is accomplished by forcing the lubricant around the piston, below the top of the piston, when at the bottom of the stroke.

Eighth.—Adjustability of the valve gear to the best effect while the engine is running, which also makes it possible to limit the speed of the engine in case of sudden loss of the load, so that it cannot damage itself by "running away."

Concerning the statement in paragraph 2, that this gear will "admit steam many times during the same stroke," "the beneficial results accomplished by this *feat*" in certain cases are as follows:

First.—In case of generating plants for electric railways it occurs every day, in fact several times a day on most roads, that the load will jump 75 *per cent.* in a minute or less when the noon whistle blows at large factories, or when theatres discharge their crowds. In such cases it may happen that an engine will "lose step" and, if alternating current is used, this is often disastrous. For instance, most of these engines cut off at 25 or 30 per cent. of the stroke, and that is absolute; it is easy to see that if the engine could get even a flash of steam when the load comes on it would keep up its speed. Again, in the case of a rod-mill engine, or any continuously running engine, if extra load is put on *after* cut-off, the engine depends on its fly-wheel to drag it through until admission; if the wheel is not sufficient, something happens. If the engine could have an additional supply of steam, the piston would keep pushing the fly-wheel instead of being dragged by it.

The racing of a marine engine when the propeller lifts clear of the water is another case.

Not only can the steam be admitted many times in a stroke, but it can also be kept *out* of the cylinder for one, two, or any number of strokes; not only this, but by a suitable arrangement of valves the engine (non-condensing) will convert itself into an air compressor (should it be desired to make a sudden stop), by drawing in air through the exhaust valves, and forcing it into the steam pipes, and thence to the boiler; so that, by cutting off the current supplying the magnets, an engine either condensing or non-condensing may be stopped, without shutting off steam, from any part of a building or ship. In conclusion, I would say that this engine has been seen by many people, both engineers and laymen, and I have repeatedly demonstrated the above facts; I would be pleased to have the opportunity to show any of the members even better results than those given in the table both with compressed air and steam.

No. 921.*

THE BURSTING OF SMALL CAST-IRON FLY-WHEELS.†

BY CHARLES H. BENJAMIN, CLEVELAND, O.

(Member of the Society.)

1. In November, 1898, the writer read a paper before this Society on the subject of small fly-wheels, detailing the results of some experiments made in the laboratories of the Case School.

The discussion of the former paper and suggestions received from various engineers since its publication, have led to further experiments on wheels of peculiar design. These experiments were all conducted under the immediate direction of the writer, and he was present at most of the destructive tests.

2. The wheels numbered 1 to 9, inclusive; were tested during the winter of 1899-1900 by senior students Messrs. Clyne and Mühlhaüser; while those numbered 10 to 16 were tested during

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* Presented at the New York meeting (December, 1901) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For previous discussions on this topic consult *Transactions* as follows:

No. 85, vol. iii.: "The Fly-wheel." William Johnson. (See *American Machinist*, May 13, 1882.)

No. 497, vol. xiii., p. 618: "A Novel Fly-wheel." Chas. H. Manning.

No. 515, vol. xiv., p. 251: "Strains in the Rims of Fly-band-wheels Produced by Centrifugal Force." J. B. Stanwood.

No. 565, vol. xv., p. 147: "Strength of Rim Joints in Fly-band-wheels." J. B. Stanwood.

No. 621, vol. xvi., p. 208: "Stresses in the Rims and Rim Joints of Pulleys and Fly-wheels." Gaetano Lanza.

No. 796, vol. xx., p. 125: "Note on the Strength of Wheel Rims." A. K. Mansfield.

No. 800, vol. xx., p. 209: "The Bursting of Small Cast-iron Fly-wheels." C. H. Benjamin.

No. 823, vol. xx., p. 944: "Rolling-mill Fly-wheels." John Fritz.

No. 835, vol. xxi., p. 262: "A Broken Fly-wheel and How it Was Repaired." Jas. McBride.

No. 839, vol. xxi, p. 317: "A Note on Fly-wheel Design." A. J. Frith.

No 907 vol. xxi., p. 955: "Determination of Fly-wheels to Keep the Angular Variation of an Engine Within a Fixed Limit." J. I. Astrom.

the present year by Messrs. Austin, Mills, and Stanford, instructors in the school. The wheels were all of cast iron, 24 inches in diameter, with proportions copied from existing wheels.

The general method of testing was similar to that used in the former experiments, but new apparatus was designed and built for greater convenience and safety.

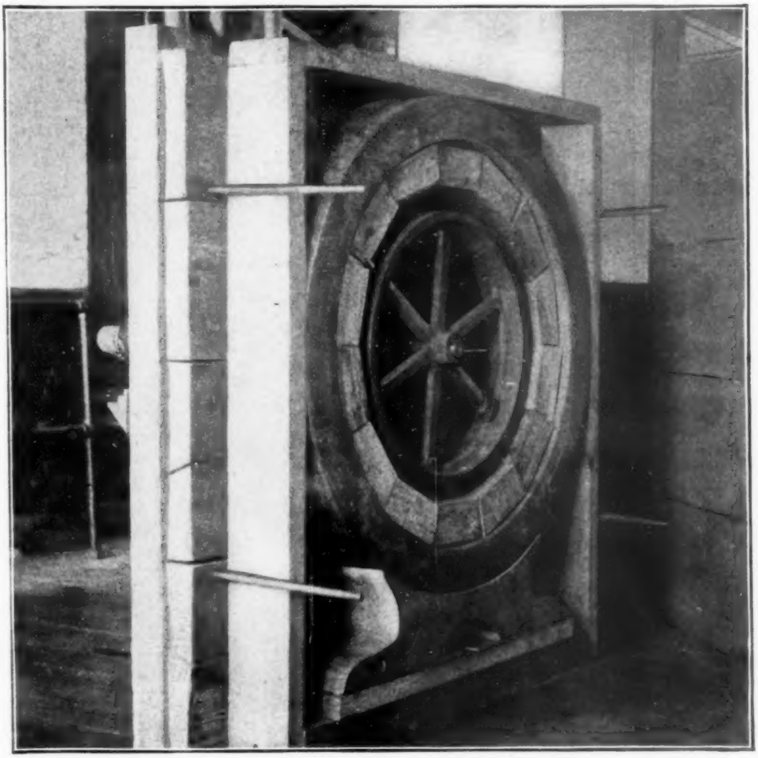

FIG. 49.—TEST CASING FOR FLY-WHEELS.

3. Former tests had shown the insecurity of a wooden shield or cage for the bursting wheels. Fig. 49 shows the form of shield used in the later experiments. A cast-steel ring 36 inches in diameter inside, and having a rim section 4 inches by 6 inches was enclosed and supported by a wooden framework, the front and back being of oak plank, 3 inches thick. To absorb the energy of the flying fragments a sectional lining of Norway pine was used, as this could be easily repaired and

renewed after each test. Fig. 50 shows the usual appearance after an explosion. During the sixteen experiments recorded but one wheel managed to escape from the shield, and this was due to the breaking of the bolts confining the side planking.

The wheels were keyed to the overhanging end of a steel shaft, $1\frac{7}{16}$ inches in diameter, running in a long bronze bushing and coupled loosely to a Dow steam turbine. Fig. 51 shows clearly the rear of the shield and the connections.

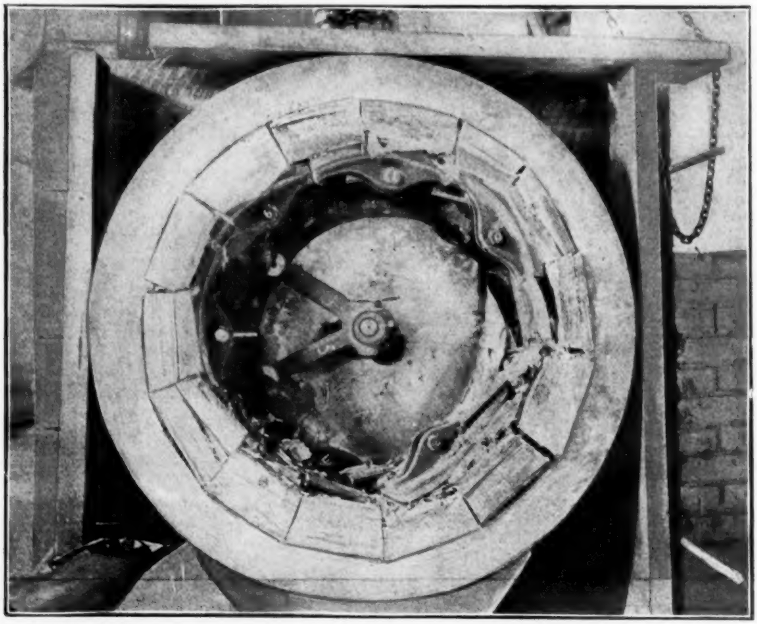

FIG. 50.

As may be seen from the cut, the speed was measured by means of a counter-shaft and belted tachometer, the speed being reduced in the ratio of one to ten. Belts made of two thicknesses of adhesive electric tape stitched together were found to be satisfactory at the speeds used, being free from slip.

The speed-counting mechanism was calibrated many times, and showed an error of less than 1 per cent. All of the wheels tested were balanced carefully by winding lead wire around the arms, close to the rim.

4. Wheels Nos. 1 and 2 were cast with solid rims, and were modelled closely from a fly-wheel 10 feet in diameter on an Allis

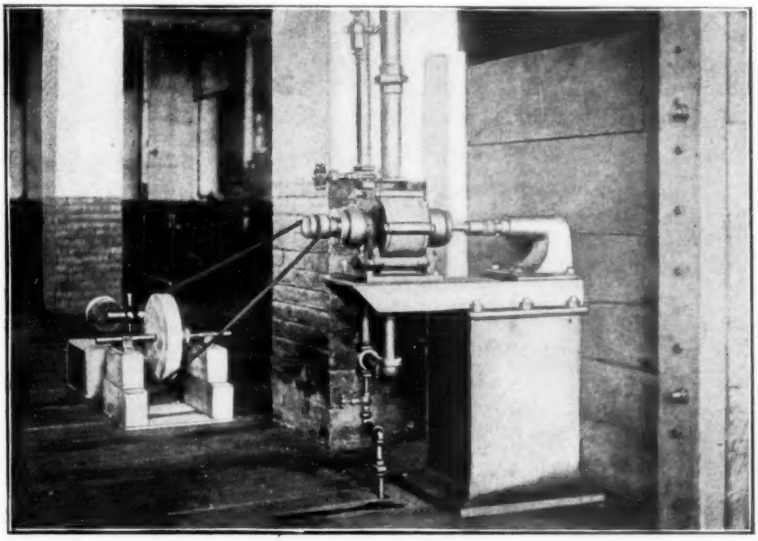

FIG. 51.—DRIVING APPARATUS FOR FLY-WHEELS.

engine. These were tested to furnish a standard of comparison for the other wheels. Fig. 52 shows the shape and proportions of this class, and Table I. gives the principal dimensions.

These two wheels failed at 3,700 and 3,850 revolutions per minute respectively, or at an average rim speed of 395 feet per second. This corresponds to a centrifugal tension of about 15,600 pounds per square inch. The fracture showed clean iron of a uniform quality.

The four wheels numbered from 3 to 6 each had two flanged

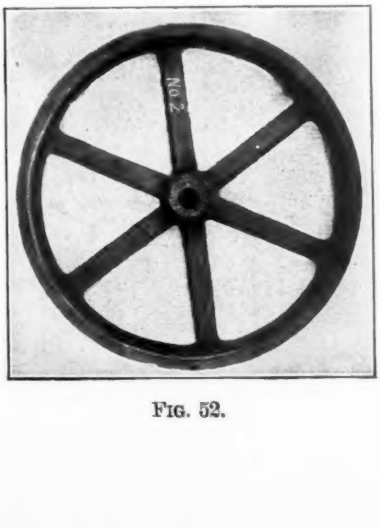

FIG. 52.

TABLE I.

DIMENSIONS.

No.	Rim.				Arms.		Weight of Wheel, Pounds.
	Diam., Inches.	Breadth, Inches.	Depth, Inches.	Area, Sq. In.	Number.	Area, Sq. In.	
1	24	4.06	0.85	3.95	6	1.08	97.2
2	24	4.10	0.80	3.65	6	1.08	94.7
3	44	4.00	0.84	3.73	6	0.95	94.0
4	24	4.00	0.84	3.73	6	0.95	91.7
5	24	4.00	0.84	3.73	6	0.95	95.0
6	24	4.00	0.84	3.73	6	0.95	96.0
7	24	2.22	2.23	4.43	8	1.67	123.0
8	24	3.00	2.50	2.46	24	0.049	60.5
9	24	3.00	2.50	2.46	24	0.049	60.5
10	24	4.03	0.80	3.67	6	0.98	96.5
11	24	4.02	0.80	3.59	6	0.92	97.0
12	24	4.02	0.80	3.59	6	0.92	95.7
13	24	4.06	0.83	4.08	6	0.92	114.5
14	24	4.06	0.82	4.08	6	0.92	116.0
15	24	4.10	0.56	2.90	6	0.95	88.0
16	24	4.09	0.57	2.92	6	0.95	87.0

joints in the rim, as shown in Fig. 53. These joints were of the same general proportions as those described in the previous paper, as may be seen by reference to Table II. At the suggestion of Mr. Jas. B. Stanwood, of this Society, they were located at points one-fourth of the distance from one arm to the next, those being approximately the points of least bending moment.

As shown in Table III., these wheels burst at from 1,800 to

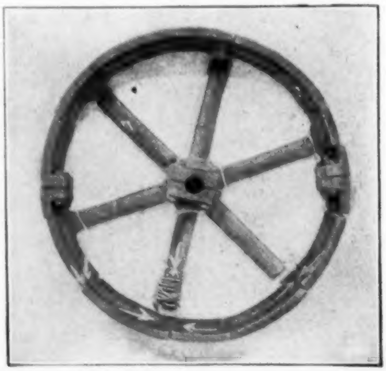

FIG. 53.

1,900 revolutions per minute, or an average rim speed of 194 feet per second. This corresponds to a centrifugal tension of about 3,750 pounds per square inch.

These wheels were, then, only one-quarter as strong as similar wheels with solid rims, and burst at one-half the speed. Comparing these with wheels of similar construction tested in 1898 (Nos. 13, 14, and 15 in the previous paper), we find that

TABLE II.

FLANGES AND BOLTS.

No.	Flanges.			Bolts.		
	Thickness, Inches.	Net Breadth, Inches.	Net Area, Sq. Inches.	Number in Joint.	Diameter, Inch.	Total Tensile Strength.
3........	1.0	2.4	2.4	4	.375	20,000
4........	1.0	2.4	2.4	4	.375	20,000
5........	1.0	2.4	2.4	4	.375	20,000
6........	1.0	2.4	2.4	4	.375	20,000
10........	1.0	2.4	2.4	4	.375	20,000
11........	1.0	2.4	2.4	4	.375	20,000
12........	1.0	2.4	2.4	4	.375	20,000
15	$\frac{5}{8}$	1.9	1.2	2	.500	18,000
16	$\frac{5}{8}$	1.9	1.2	2	.500	18,000

TABLE III.

BURSTING SPEEDS.

No.	Bursting Speed.		Centrifugal Tension.	
	Revolutions per Minute.	Feet per Second.	Pounds per Square Inch.	Total on Rim.
1................	3,700	387	14,980	59,600
2................	3,850	403	16,240	59,000
3	1,800	188.5	3,570	13,560
4	1,850	193.6	3,750	14,000
5................	1,900	199	3,950	14,780
6................	1,850	193.6	3,750	14,000
7................	2,450	256.5	6,600	29,400
8................	4,050	424	17,970	44,000
9................	4,050	424	17,970	44,000
10................	1,570	164	2,700	9,920
11................	2,100	220	4,800	17,200
12................	2,200	230	5,300	19,000
13................	3,650	382	14,600	59,600
14................	3,850	403	16,300	66,500
15................	2,080	218	4,800	13,900
16	2,175	228	5,200	15,200

moving the joint from the centre to the quarter point has made no appreciable difference in the strength.

This is, doubtless, due to the fact that the heavy mass of the flanges and bolts locates the bending moment at or near them. "Where MacGregor sits, there is the head of the table."

5. Fig. 53 shows the general manner of fracture of these wheels; strange to say, the joints usually remained intact—the bolts being slightly stretched—and the rim broke close to the joint, as shown in the cut.

6. The practically instantaneous character of the explosion is illustrated in Fig. 54, which shows the appearance of wheel No. 6 after rupture. With but one exception, each piece of the

Fig. 54.

rim was embedded in the wood lining in its proper place and remained there, indicating a nearly simultaneous movement of the fragments. The lining was rotated in the steel ring through a considerable angle.

The combined tensile strength of the bolts in the flange joints was about 20,000 pounds, or less than one-third the strength of the solid rim, which is about the maximum ratio possible with this style of joint.

7. Wheel No. 7 was a complete working model of a fly-wheel for a blowing engine, and was copied from drawings furnished by a well-known firm of engine builders. The construction is clearly shown in Fig. 55, and the dimensions are given in Table I The joints in the rim were carefully fitted and the links shrunk in. This wheel burst at 2,450 revolutions per minute, and a rim

speed of 256 feet per second, which indicates a centrifugal tension of about 6,600 pounds per square inch, and shows that this wheel is nearly twice as strong as those just described. As may be seen by reference to Fig. 56, the wheel broke in every

FIG. 55.

instance through the smallest section of the rim near the joint, the links remaining intact. It is interesting to note that every bolt in the hub was shaved off clean as by a knife, each arm pulling out in this way.

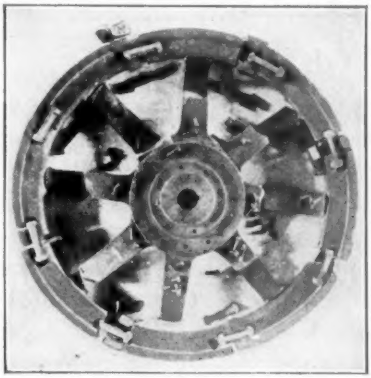

FIG. 56.

8. Soon after the publication of the previous paper, the writer had some correspondence with Prof. Archibald Sharp, of London, Eng., which resulted in the latter's sending to this country two model wheels to be tested, which are numbered

8 and 9 in the tables, and were constructed as shown in Fig. 57. The rims were solid, of an I section, and were made of a close grained cast iron having a high tensile strength.

Each wheel had 24 spokes of steel wire, 12 on each side of the central plane. A pair of spokes constituted a loop, fastened at each end to the rim with a thread and nut, and passing spirally around the hub in a groove cut for that purpose. By tightening up the nuts at the rim the wheel could be accurately centred, and sufficient friction caused at the hub to prevent slipping.

The two wheels failed at precisely the same speed, 4,050 rev-

FIG. 57.

olutions per minute, or a rim speed of 424 feet per second. This would correspond to a centrifugal tension of nearly 18,000 pounds per square inch, and is probably the maximum speed attainable with a cast-iron rim. The appearance after rupture is shown in Fig. 58.

The rims usually broke through the holes where the spokes were fastened, and the spokes themselves broke at one or both ends, where threaded.

The spokes had been adjusted to a uniform tension before the test by "tuning" them to the same pitch. This uniformity of tension, and the large number of spokes, must have prevented any serious bending of the rims, so that the latter failed by direct tension.

The speed given is the highest attained in any of the experiments One fact in connection with this last experiment de-

serves mention. It was found impossible at first to bring these wheels up to the desired speed; at about 3,000 revolutions per minute the speed would remain constant, and no increase of steam pressure would avail to change it. Becoming convinced that this was due to air resistance on the spokes and cross flanges of the rim, the writer had the wheels inclosed by disks of Russian iron, wired together and revolving with the wheels. No further difficulty was experienced, and the bursting speed was attained within two minutes of the time of opening the throttle.

Similar devices had to be used with wheels numbered 13 to 16, inclusive.

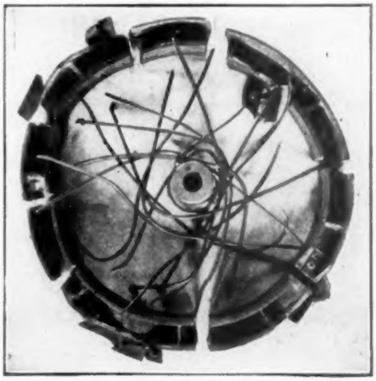

FIG. 58.

9. Wheels numbered 10, 11, and 12 had the usual flanged joints, located midway between the arms and fastened with four $\frac{5}{8}$-inch bolts. The joints in wheel No. 10 were unsupported, while those in wheels Nos. 11 and 12 were strengthened by steel tie rods running from hub to joints and bolted at each end, as shown in Fig. 59. The net tensile strength of each tie rod was about 5,000 pounds. The two rods connected to each joint had then a combined tensile strength about two-thirds that of one arm. Wheel No. 10 burst at 1,570 revolutions per minute, a rim speed of 164 feet per second, which is only about five-sixths of the speed usually attained by this class of wheel. The break was in the rim just beside the flange, and the low speed would indicate a poor quality of iron.

10. Wheels Nos. 11 and 12 broke at 2,100 and 2,200 revolu-

tions per minute, respectively, or at an average rim speed of 225 feet per second. Comparing these with wheel No. 10, as the three wheels were of the same iron and identical in every respect

FIG. 59.

save the tie rods, we find an increase of from 34 to 40 per cent. in the bursting speed due to the use of the tie rods. This corresponds to an increase of nearly 100 per cent. in the strength of the joint. If the tie rods had been more carefully designed and constructed, a greater speed could have been attained.

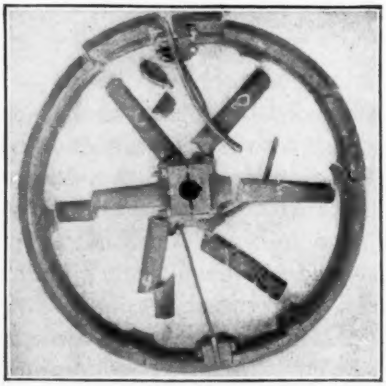

FIG. 60.

Fig. 60 shows the appearance of wheel No. 12 after rupture. The ties broke through the bolt holes at one or both ends, the bolts remaining intact with but one exception.

11. Wheels Nos. 13 and 14 were of peculiar construction, as may be seen from Fig. 61. The rim of each was cast in one piece, while the hub and arms formed a spider, also in one casting. The arms were jointed to the internal flanges of the rim by $\frac{5}{8}$-inch steel bolts, giving one degree of freedom. The object of this construction was two-fold:

First.—To relieve the bending moment at the junction of the rm and rim.

Second.—By concentrating more weight near the arms to stretch these latter and thus relieve the bending moments in the rim midway between the arms.

These two wheels burst at 3,650 and 3,850 revolutions per

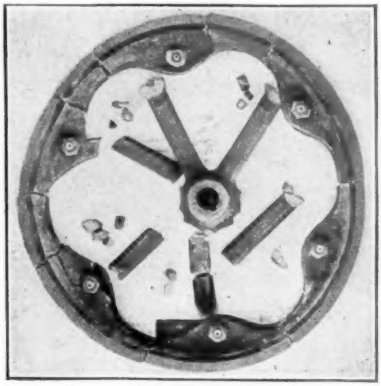

FIG. 61.

minute, or an average rim speed of 392 feet per second. Comparing these figures with those given for wheels Nos. 1 and 2, we find that the speeds are practically the same. There is no apparent advantage in the special construction just described over the ordinary method of casting the spokes and hub with the rim.

Fig. 61 shows the appearance of wheel No. 13 after rupture. The arms all broke at the eye near the rim, the bolts not being injured. Only one web was fractured. Fig. 50 shows the wheel immediately after the explosion, the front of the shield and one cover plate being removed. The embedding of the rim fragments in the wood lining in their proper order is clearly shown, the same as in Fig. 54. The absence of any tearing or rending sound and the single sharp report, like a small cannon, also evi-

denced the practically instantaneous character of the explosion.

Wheel No. 14 was the one which escaped from the shield, as has already been noted. The wood lining was reduced to fine splinters, the cast-steel ring, weighing over 800 pounds, was rotated through an arc of 12 inches, a $\frac{3}{4}$-inch bolt was broken short off, and the 3-inch oak planking split and torn.

12. Wheels Nos. 15 and 16 were also of special construction, as seen in Fig. 62. The hub and arms were cast together as a spider and bolted to pads on the rim. The two joints in the rim came over arms, and the rim between the arms was reinforced by elliptic webs. The construction is a slight modifi-

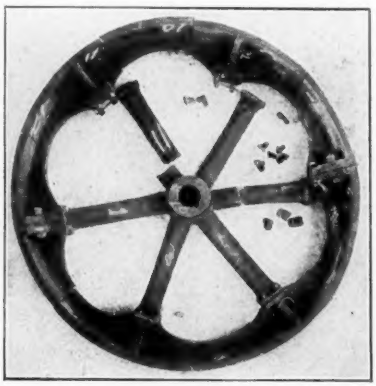

FIG. 62.

cation of that suggested by Mr. A. J. Frith, of this Society, in a paper read in December, 1899.* The *raison d'être* of this form of wheel is explained by Mr. Frith in his paper. Briefly, this construction is intended to stretch the arms more and bend the rim less than the common form.

These two wheels burst at 2,080 and 2,175 revolutions per minute, respectively, or an average rim speed of 223 feet per second. Fig. 62 shows the manner of failure. The ends of the arms failed in several different ways: sometimes it was the screws that broke, sometimes the lugs on the arm, and sometimes the pad on the wheel. The rim usually broke at points midway between the arms. In wheel No. 16 the joints remained intact.

* No. 839, vol. xxi., p. 317.

It will thus be seen that Nos. 15 and 16 were of practically the same strength as Nos. 11 and 12, but only about one-third as strong as wheels with solid rims.

13. The conclusions of the previous paper are confirmed by these further experiments. For wheels of moderate size correctly proportioned the solid rim is by far the safest form, and will require a speed of from 350 to 400 feet per second to produce rupture. The stress due to bending is so small as to be negligible.

Jointing the arms at the rim and bracing the rim by internal webs have no important effect on the strength.

Joints in the rims are the principal source of weakness, especially if located between the arms. Probably no joint can be made for a rim of solid cross-section which will be more than one-third as strong as the rim itself.

Hollow rims will permit of a much more efficient joint, as has been shown by Mr. John Fritz in his paper, read at the meeting of this Society in May, 1899.*

The joints in Mr. Fritz's wheel are practically as strong as the rest of the rim. This construction is hardly possible in wide-faced band wheels such as are used on most shop engines. Joints similar to those shown in Fig. 62 are probably the best that can be devised for this type of wheel. If joints are located midway between the arms they should be reinforced by tie rods leading to the hub.

The English wheels, Nos. 8 and 9, show clearly the advantage of numerous arms on any type of wheel. Even if the rims were jointed, such wheels would prove their superiority to those with the ordinary arms in maintaining their shape at high speed.

DISCUSSION.

Mr. Arthur J. Frith.—The experiments of Mr. Benjamin are of great interest to the investigation of the correct method of designing fly-wheels, and he deserves the thanks of the Society for his continued efforts. The destruction of fly-wheels under high speed would seem to be the court of last resort, though we must not lose sight of the fact that the results obtained may be confined to very small wheels with rims that are practically of

* No. 823, vol. xx., p. 944.

bulky dimensions. Its results are strong evidence that "the stress due to bending is so small as to be negligible in small, bulky-rimmed wheels," as stated in paragraph 13. I believe, however, that if wheels Nos. 13 and 14 had had a solid web that it would have removed the doubt that exists, that the absence of the signs of bending might be due to weak connections rather than to incorrect theory. Certainly the description states that it was the eye in the arm that gave way; what the results would have been if the eyes had been strong enough to break the arms is left in doubt.

The same may be said of the breaking of Nos. 15 and 16. It was the screws, lugs, and pads that failed, and it looked as if these might have been made stouter, the theory of construction being still possibly correct.

In my paper to the Society, in which this construction was suggested, attention was drawn to the necessity for a careful design of these details, those shown in the sketch submitted being stated to be merely suggestions and too light. For the reasons mentioned, the conclusions drawn from these experiments are not as convincing as might be desired.

It may be a fact that there are some classes of fly-wheel rims in which the bending action is so slight that it may be neglected; but this is certainly not true of wide band-wheels with a single system of arms, and the design suggested in my paper, December, 1899, was especially aimed to remedy a dangerous tendency in that class of fly-wheels; that it would not do so, is a conclusion that cannot be drawn from this set of experiments. It is hoped that Mr. Benjamin may be able to repeat the experiments with wheels similar to Nos. 15 and 16, but with stout fastenings and a wide overhanging shallow face, and that it may be compared with a solid wheel or pulley, with a face equally wide and shallow; if this be done, it will complete a very interesting series of experiments, and I believe that the good results obtained will repay his efforts, and merit the grateful appreciation of this Society.

The tests would lead us to believe that comparatively shallow-faced wheels Nos. 15 and 16 gave equal results with deep-rimmed, narrow wheels Nos. 6 and 7; but are they comparable at all? Their speed of rupture is that of their weak joints, and the pad joints of Nos. 15 and 16 could have been made two or three times as deep, or fastened with steel bands, shrunk on. It would

be interesting to know what results would have been obtained if they had been stout enough to break the arms.

Mr. Albert A. Cary.—The Society certainly owes many thanks to Professor Benjamin for what he has done in the way of fly-wheel investigation, and we are certainly learning more about them than we ever knew before. Fig. 52 is described as a duplicate of the regular Corliss engine fly-wheel, but it is not a duplicate of the wheel often found on Corliss engines, in which the rim is comparatively quite thin; experiments with wheels of that kind might develop some further interesting facts, and certainly in those the bending would not be negligible, but would be very considerable. It is interesting to note in Fig. 57 that the breaking stress was about the same as that of the cast-iron itself in tension, and I would like to ask Professor Benjamin if he has tested in tension the material of which the wheel shown in Fig. 57 was made so as to make the comparison directly and find what percentage of the tensile strength was obtained.

Mr. R. H. Soule.—Mr. President, in paragraph 13, embodying conclusions derived from these experiments, it is stated that "for wheels of moderate size, correctly proportioned, the solid rim is by far the safest form, and will require a speed of from 350 to 400 feet per second to produce rupture." I hope that Professor Benjamin, either now or when he writes up his closure, will let us know what he considers wheels of moderate size; that is, up to what limit of diameter the solid rim is the best form. That is left somewhat indefinite, and very likely from his experiments and his general knowledge on the subject he can give a definite limit.

Mr. H. G. Reist.—In the middle of paragragh 13 it is stated that probably no joint can be made for a rim of solid cross-section which will be more than one-third as strong as the rim itself. It seems to me that the wheel shown in Fig. 55 probably has a stronger section than that. At any rate, I believe it can readily be made to have from 50 to 60 per cent. of the strength of the solid cross-section.

*Prof. C. H. Benjamin.**—At the session of the Society on Wednesday morning, some allusion was made by my friend Mr. Boyer to the fact that we stopped with 24-inch fly-wheels, and suggesting the desirability of going further and trying to burst wheels six, ten, and perhaps twelve feet in diameter. I think

* Author's Closure, under the Rules.

there are other considerations besides financial ones which would deter me from making the wheels very much larger (laughter), and I think that if any one were present at the bursting of a two-foot wheel he would be satisfied that the experiment had reached its limit. (Laughter.)

I will answer one or two of the questions which have been asked. In the first place, I will say that in the wheel shown in Fig. 62 the arms were broken in several instances. The Society will readily understand that these wheels, as we found them after rupture, did not look like the picture, and that it was quite a difficult matter sometimes to put the Chinese puzzle together. We afterwards adopted the method of marking the pieces, so that we could tell which was which after rupture. Even then it was impossible to tell what broke first. In some cases it is possible; that is, by knowing how a joint would break, in what way it would naturally fail, we can tell which joint broke first and which broke second. But it is difficult to tell whether an arm broke first in one place or in another. The arms in many cases did break. If we had had more time we should have increased the strength of the joint, and have in that way reached a point where the arm would always break, and not the joint. We did this, however, with the flanges. With the ordinary flanged joints, we first, in bursting the wheels, broke the flanges; we then increased the thickness of the flanges until the bolts broke, then put in larger bolts and broke the flanges again, and so kept on until we got so large a flange that its centrifugal force was enough to wreck the wheel. A question was asked with regard to the term "wheels of moderate size." I had reference to the natural limit for transportation purposes; that is, wheels over eight feet in diameter are usually made in two parts, and wheels over sixteen or seventeen feet in diameter made in sections. I made no experiments which would enable me to form any conclusions in regard to the limitations as to strength. It is simply a question of transportation. All the joints in flat rims which have been shown in these papers are less than one-third the strength of the solid rim by calculation and by testing. Joints in deep rims can be made stronger than this. With regard to the tensile strength of the material, with the English wheels we could not obtain that, as we had no specimens. With most of the wheels we had test specimens cast out of the same ladle as the wheel itself, and in that way were able to get the modulus of rupture and the tensile strength of the cast iron; for

most of the wheels the tensile strength was about 18,000, and the modulus of rupture about 35,000.

I am in hopes to have ready in a few months a new testing apparatus, when I can burst wheels up to four feet in diameter, and with rims not exceeding one foot in width.

I would be glad to have engine builders furnish me with model wheels not larger than the sizes mentioned, and would test them free of charge.

No. 922.*

AN EXPERIMENT ON THE EFFECT OF CLEARANCE ON THE ECONOMY OF A SMALL STEAM ENGINE.†

BY ALBERT KINGSBURY, WORCESTER, MASS.

(Member of the Society.)

1. THE experimental work to be described was undertaken under the advice and supervision of the writer, as the basis of a thesis by Mr. Irving A. Colby and Mr. Lewis H. Kenney, of the Class of 1899, at the New Hampshire College. The object of the experiment was to determine the effect of varying clearance upon the steam consumption of a small automatic engine. The plan for the work was to make several series of runs, each series at a constant indicated horse-power, with variable clearance, and with boiler pressure, quality of steam, and speed of engine constant throughout all the series. Only one such series was actually completed; but the results, though covering only a narrow range of conditions, appear to justify publication, in view of the small amount of experimental information thus far available upon this subject.

2. The engine tested was built by H. B. Payne & Sons, of Elmira, N. Y. It was of the horizontal type, cylinder $5\frac{1}{16}$ inches bore, stroke 7 inches, with a plain slide valve controlled by a shaft governor. With this type of valve it was, of course, impracticable to control independently the indicated power, the expansion, and the compression; hence, with varying clearance there was also some variation in the expansion and the compression. The engine had been in use for some years, but was especially prepared for these tests by reboring the cylinder, fitting a new piston and piston rings, and reseating the valve.

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* Presented at the New York meeting (December, 1901) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For further discussion on this topic consult *Transactions* as follows:
No. 710, vol. xviii., p. 176: "The 'Promise and Potency' of High-pressure Steam." R. H. Thurston.

3. For absorption of the power and control of the speed, the engine was belted to the line shaft in the laboratory; which shaft was driven by a larger engine regularly supplying the power for the shops. Thus the speed of the engine was made nearly constant and independent of its own governor, and the use of a dynamometer was avoided.

4. The indicated power of the engine was adjusted and maintained at the desired constant value, by varying the valve travel as in the ordinary operation of the engine, the adjustment being made by screw stops fixed upon the arms of the governor wheel, limiting the inward motion of the governor arms under the spring tensions, but leaving the governor free to act in case of accidental excessive speed. The speed, as controlled by the belt, was somewhat slower than the slowest speed of the engine when under the normal control of the governor. The valve was set to give nearly equal work in the two ends of the cylinder when the clearance had its normal value, and the only changes in its motion thereafter were those due to the necessary slight changes in the angular advance and throw of the eccentric as the stops were adjusted in the governor.

5. The desired variations in the clearance volume were made by inserting cast-iron rings under the back cylinder head. These rings were turned to pass inside the studs, and were bored to the diameter of the counterbore; the metal was about $\frac{3}{8}$ inch thick. The original clearance, which was about 13 per cent. of the piston displacement, was reduced to the minimum of 10.82 per cent. by screwing a cast-iron disk to the inner face of the cylinder head. As it was impracticable to vary the clearance in the crank end by the required amount, the engine was made single-acting by stopping the forward steam passage with a block of lead, and that end was left open to the air through about six feet of $\frac{1}{2}$-inch pipe screwed into the indicator hole. This arrangement served incidentally to show that there was no appreciable piston leakage at any time during the tests. It probably produced some increase in the already high water rate of the engine, but the magnitude of this effect would be difficult to estimate.

6. Steam for the engine was taken from a main in which the gauge pressure varied from about 75 to about 85 pounds. The arrangements for securing constant pressure and quality of steam at the engine were as follow: The steam passed first

through a $1\frac{1}{2}$-inch Mason reducing valve, fitted with a regulating wheel, from which cords were led to a point near the engine; by this means the operators kept the pressure constant at 70 pounds, as shown by a gauge on the pipe near the engine. After passing the reducing valve the steam entered a reservoir of about 0.6 cubic foot capacity; thence it passed through a vertical "Straight-Line" separator, and a $1\frac{1}{2}$ inch vertical pipe and valve to the steam chest.

A throttling calorimeter was attached to the steam pipe just below the separator; it was operated at atmospheric pressure, and the thermometer was exposed directly to the superheated steam. The exhaust was condensed and weighed by discharging it into a barrel of water standing on a platform scale.

7. A Thompson indicator was used, with 60-pound spring. To eliminate the effects of inertia of the drum of the indicator, the drum spring was made of such stiffness that the free oscillations of the drum were nearly synchronous with the strokes of the engine, thus insuring almost constant tension in the indicator cord when running. The cord was not more than two feet in length. The reducing motion was rigid, free from lost motion, and involved no geometric error.

8. The strokes of the engine were registered by a continuous counter. The volumes of the clearance were determined by adding to the minimum clearance, as measured by the usual method of filling the space with water, the computed volumes of the successive rings placed under the cylinder head.

9. All the runs were made at the same mean effective pressure as nearly as practicable. Since each change of clearance affected the expansion and compression ratios, it was necessary to adjust the valve travel for each change of clearance, in order to maintain the mean effective pressure constant. The time required to make this adjustment closely was considerable, hence some variation was allowed; the mean effective pressure thus ranged from 18.7 to 21 pounds. This corresponds to a rather small load for the engine, but the original intention of making other series of runs at higher loads could not be carried out in the available time.

10. The routine of testing was as follows: The desired clearance was provided; the governor was set by trial for the required constant mean effective pressure; the engine was then run for ten or fifteen minutes, the exhaust discharging into the

atmosphere. At the starting signal the exhaust was diverted to the condensing tank by a branch pipe and valves, and the speed counter was connected. Readings of the calorimeter temperature, gauge pressure, and room temperature, and also indicator diagrams were taken every five minutes, beginning two and one-half minutes after the start. At the end of the thirty-minute run the exhaust was again discharged into the atmosphere, and the stroke-counter was disconnected. Two such runs were made for each value of the clearance, except in two cases, when three runs were made.

11. Specimen indicator diagrams for the several clearances are shown in Fig. 63, and a summary of the numerical data and results is given in Table I.:

The mean calorimeter temperature of 259.7 degrees Fahr. corresponds to 1.6 per cent. moisture in the steam; the extreme temperatures, 254 degrees and 264 degrees, to 1.3 per cent. and 1.9 per cent. respectively.

12. The results of the tests are shown in the diagram (Fig. 64). In this diagram the only points that do not fall into a fair curve are those for runs Nos. 7*a*, 8*a*, 8*b*, 10*a*, and 10*b*, in all of which runs there existed the exceptional condition of poor cylinder lubrication, the rubbing surface being found dry and abraded at the end of the run. Only one result obtained under this condition (7*b*) falls on the curve. This run was made after an interval of several hours, and the lubrication may not have been defective throughout the run. Runs 8*a* and 8*b*, made consecutively with poor lubrication, show the low water rate common to the runs made under this condition, but run 8*c*, made at a later date with good lubrication, gives a result falling on the curve. Thus in each of these cases of excessive friction, with the single exception of 7*b*, the water rate is about 10 per cent. lower than that which would render all the results fairly concordant.

13. This evidence, as far as it goes, points distinctly to a reduction in the cylinder condensation by the heating of the piston and cylinder through excessive friction. It is not improbable that the minor variations of those results that are nearly concordant are also largely due to variations in the supply of cylinder oil and in the friction of the piston and the valve. The supply of oil was scanty throughout the tests, only one or two small drops per minute, the object being to avoid the well-known effect of a free supply of oil in reducing cylinder condensation,

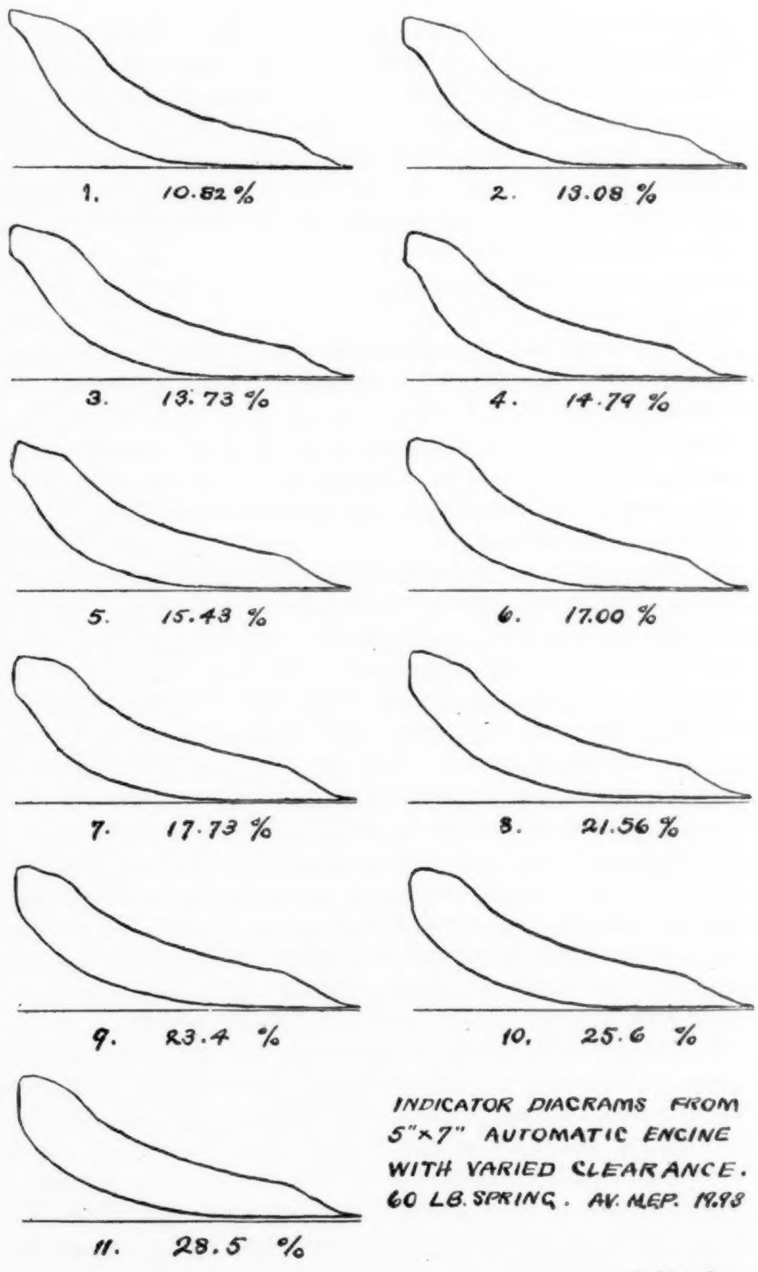
1. 10.82 %
2. 13.08 %
3. 13.73 %
4. 14.79 %
5. 15.43 %
6. 17.00 %
7. 17.73 %
8. 21.56 %
9. 23.4 %
10. 25.6 %
11. 28.5 %
INDICATOR DIAGRAMS FROM
5"×7" AUTOMATIC ENGINE
WITH VARIED CLEARANCE.
60 LB. SPRING. AV. M.E.P. 19.98
A. Kingsbury.

FIG. 63.

TABLE I.

MEAN DATA AND RESULTS OF TESTS. 5 BY 7 AUTOMATIC ENGINE.

Clearance per cent. piston disp.	Run No.	Date, 1899.	Room temperature, Deg. Fahr.	Calorimeter temp., Deg. Fahr.	Gauge pressure.	Revolutions per minute.	M. E. P. average for run.	I. H. P. Mean for run.	Water per I. H. P. per hour, pounds.	Mean Water, per I. H. P. per hour, pounds.
10.82	1 *a*	May 2	87	262	70	227.6	19.4	1.57	53.5	
	1 *b*	" 22	83	258	70	230.5	20.7	1.70	50.4	
	1 *c*	" 24	83	256	70	224.6	19.3	1.55	52.0	51.9
13.08	2 *a*	" 2	86	264	70	224.5	19.7	1.57	52.6	
	2 *b*	" 2	88	262	70	228.5	19.6	1.59	51.0	51.8
13.73	3 *a*	" 3	85	263	70	229.1	19.0	1.55	52.4	
	3 *b*	" 3	86	263	70	231.0	19.4	1.59	54.0	53.2
14.79	4 *a*	" 5	89	264	70	226.7	19.3	1.55	53.2	
	4 *b*	" 5	87	263	70	230.5	19.0	1.56	53.2	53.2
15.43	5 *a*	" 8	88	264	70	229.5	19.3	1.58	52.8	
	5 *b*	" 8	88	264	70	227.5	19.5	1.58	53.8	53.3
17.00	6 *a*	" 8	88	261	70	223.3	19.7	1.56	55.2	
	6 *b*	" 8	87	261	70	222.1	19.7	1.56	53.2	54.2
17.73	7 *a**	" 8	87	259	70	225.9	20.1	1.62	49.8	49.8
	7 *b*	" 9	86	260	70	222.8	19.2	1.52	54.0	54.0
21.56	8 *a**	" 9	89	260	70	223.8	20.8	1.66	48.6	48.4
	8 *b**	" 9	89	260	70	224.5	20.7	1.66	48.2	
	8 *c*	" 22	83	257	70	231.3	20.5	1.69	54.4	54.4
23.4	9 *a*	" 17	88	256	70	228.5	20.6	1.68	54.8	
	9 *b*	" 17	86	256	70	232.3	20.5	1.69	55.6	55.2
25.6	10 *a**	" 15	86	260	70	224.6	20.1	1.61	50.0	
	10 *b**	" 15	88	261	70	223.8	20.5	1.63	49.4	49.7
28.5	11 *a*	" 16	84	256	70	226.6	20.2	1.63	53.8	
	11 *b*	" 16	85	254	70	225.6	20.6	1.66	55.4	54.1
32.5	12 *a*	" 16	88	255	70	229.3	20.2	1.65	56.8	
	12 *b*	" 16	87	254	70	230.4	20.7	1.70	54.4	55.6
Average			86.6	259.7	70	227.1	19.93	1.61		
Highest observed value			91	264	70	232.3	21.0	1.79		
Lowest observed value			82	254	70	222.1	18.7	1.50		

* In these runs the cylinder lubrication was insufficient, and the bore of the cylinder was found dry and abraded at the end of the run in each case.

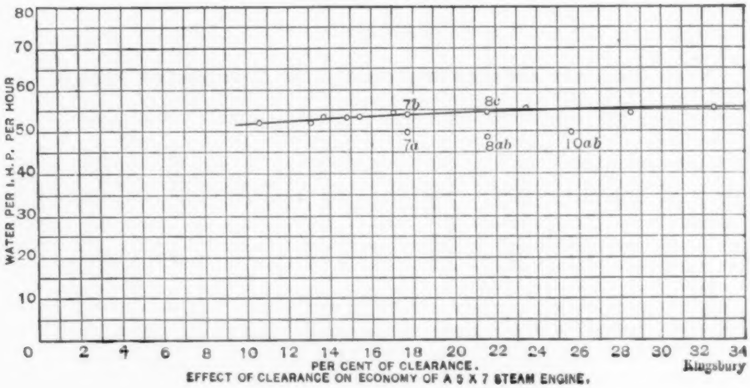

FIG. 64.

but no especial effort was made to keep the rate of oil-feed constant.

14. The curve of results, as drawn, shows a regular but not great increase in the water rate with increase of clearance. The increase of clearance, however, is accompanied by an increase in the pressure at release, corresponding to less complete expansion; also by a decrease in the pressure at the end of compression. The increase in the water rate can therefore be regarded only as the joint effect of increased clearance with decreased expansion and decreased compression, under the relations of these variables as determined by the slide valve and for the given constant indicated power.

ADDED AT THE MEETING.

The areas to which the steam was exposed in the cylinder and steam passages were as follows:

	Area in Square Inches for Minimum Clearance. 10.82 per cent.	Area in Square Inches for Maximum Clearance. 32.5 per cent.
At beginning of stroke............	111.2	135.7
At end of stroke..................	222.6	246.9

DISCUSSION.

Mr. Henry E. Longwell.—The ordinary single valve engine, in which the cut-off is effected by a variable throw eccentric, must

of necessity have a certain amount of clearance, or it would not run at all.

The amount of clearance, within certain limits, fixes the exhaust-lap. As we reduce clearance, we must, in order to avoid excessive compression, cut off exhaust-lap. Reduction of exhaust-lap means earlier release with consequent free expansion losses. It also means exposing the cylinder to exhaust temperature for a longer period of time.

I think that, if it had been a mechanical possibility for Mr. Kingsbury to have carried out his experiments with clearances materially less than 10.82 per cent, his curve of steam consumption would have taken a very abrupt upward turn at the left-hand end.

I believe that a certain amount of clearance, far from being the unmitigated evil that we are prone to believe, has under many conditions, if judiciously used, decided economic advantages.

If I were afflicted with a badly underloaded non-condensing Corliss engine with small clearances, I should expect to effect a better cure by increasing clearance and compression than by any other means short of putting on a smaller cylinder. I should expect the increased clearance to prevent a ruinously low terminal pressure, and the earlier compression to reduce the exhaust-waste.

To illustrate the way in which clearance may be utilized to modify the character of the curve representing the co-relation between load and steam consumption, I would call attention to the diagram submitted herewith (Fig. 65.)

Curve *AA* is plotted from data given on pages 126 and 127 of Mr. Geo. H. Barrus' work entitled "Engine Tests." The results were obtained from a pair of 16-inch by 42-inch Corliss non-condensing engines running at about 85 revolutions per minute, for which determinations of steam consumption were made at six different loads corresponding to mean effective pressures varying from 5.03 to 48.4 pounds per square inch. The small circles mark the height of the ordinates representing the actual steam consumption. The observed quantities for mean effective pressures of 13.8 and 20.2 pounds do not fall on a smooth curve, so I have taken the liberty of assuming that the consumption at 20.2 pounds is a little better than the measurements shown, and the consumption at 13.8 pounds is a little worse.

Curve *BB* is plotted from a test which I made about five years ago on an 18 × 16-inch two-cylinder, single-acting, single valve,

simple, non-condensing engine, for which determinations of steam consumption were made at six different loads corresponding to mean effective pressures ranging from 6.12 to 51.4 pounds per square inch. I would be more explicit and say that it was a Westinghouse standard automatic engine, were it not so injudicious to antagonize public opinion with the statement that this much-slandered machine is capable of developing an indicated horse-power on a little less than 27 pounds of steam per hour, even under the most favorable conditions.

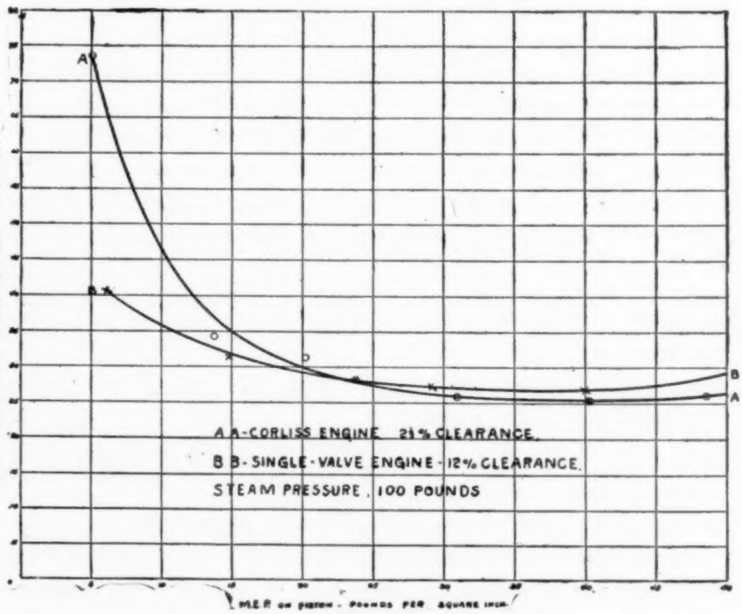

FIG. 65.

The observed quantities are indicated by crosses, and all fall very closely on a smooth curve. The diagram has not been extended quite far enough to the right to include the observation at 51.4 pounds mean effective pressure. It was actually 29.7 pounds, and the curve, if prolonged, will pass through this point.

The clearance of the Corliss engine is reported as 2½ per cent. The clearance of the single-valve engine is about 12 per cent. The steam pressure in both instances was 100 pounds, and the steam was assumed to be commercially dry, no corrections for moisture having been made.

These curves cross at about 24 pounds mean effective pressure, the engine with small clearance having the advantage on the higher mean effective pressures and the engine with the large clearance having the advantage on the lower mean effective pressures.

A casual inspection of the diagram will, I think, make it apparent that, apart from any commercial considerations other than steam consumption, the character of the load on an engine is one factor in determining whether a certain amount of clearance in excess of the minimum possible is a detriment or a benefit. It is my own opinion that in an engine underloaded all the time, or with a widely varying load which averages much below normal, the clearance is beneficial, or, more strictly speaking, can be made beneficial.

The amount of clearance which can be used to advantage undoubtedly bears some relation, yet to be determined, to the initial pressure and the back pressure. The illustration submitted is not intended to be general, but is simply a comparison between two widely differing types of engines of about the same nominal capacity, one generally accepted as the acme of economy and the other as a synonym for wastefulness. It also applies only to steam pressure of 100 pounds and atmospheric back pressure. Neither is it asserted that 12 per cent. is the best amount of clearance for these conditions, nor that the clearance has been used to the best possible advantage.

In our investigations as to the effect of clearance, we are generally so fixed in our belief that it is a bad thing that we are apt to confine our efforts to determining how bad it is, and we can usually find plenty of trouble if we hunt for it diligently. A line of systematic endeavor to ascertain whether or not clearance has some good points which, if properly utilized, would more than offset its bad points, might result in our finding that it is something like a medicine—its good or bad effect depending on how much one needs it, and how intelligently he uses it.

Mr. H. H. Suplee.—In experiments upon clearance, there are naturally involved also experiments upon condensation, and I should like to call the attention of the meeting to some of the latest experiments which have been made by Professor Dwelshauvers at the University of Liège; probably many of you are familiar with his earlier experiments, but I have put two diagrams

upon the board from one of his latest publications which has not yet appeared in English. He found that excessive compression was wasteful, and conducted a long series of experiments to find

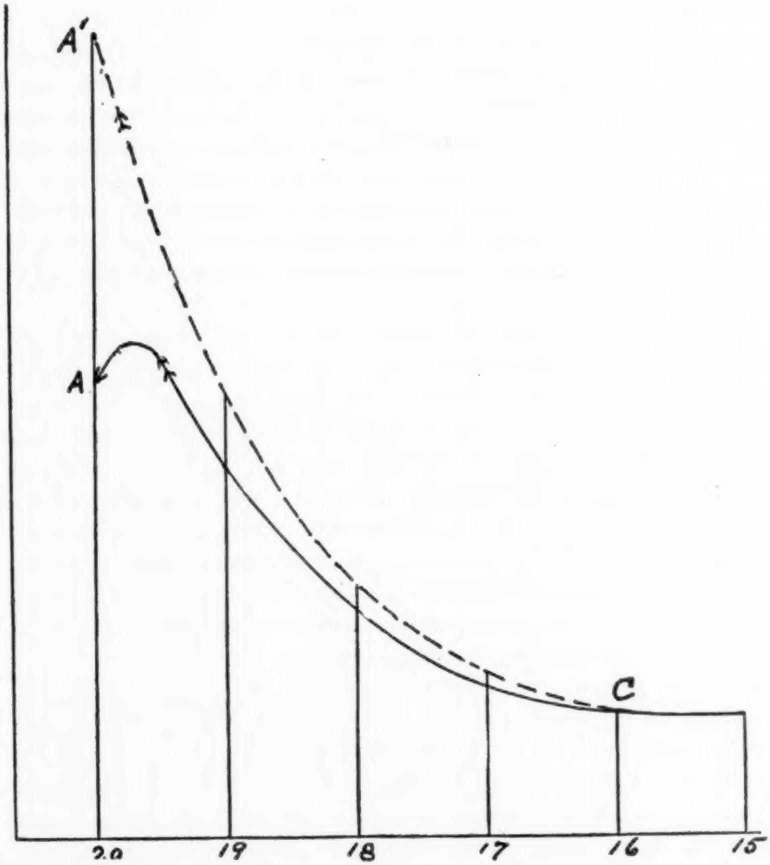

FIG 66.—CURVES FROM PAPER OF PROFESSOR DWELSHAUVERS-DERY, *Revue de Mécanique*, JULY, 1901. THE HOOK OF CURVE *AC* IS DUE TO CONDENSATION OF THE COMPRESSED STEAM; THE DOTTED CURVE TO *A*' SHOWS THE COMPRESSION OF AIR, PROVING THE ABSENCE OF LEAKAGE.

the reason; in every case, he found that where the compression was carried to a high point a peculiar hook was produced, as seen slightly in the lower line, Fig. 66, which resembles some of those given in Professor Kingsbury's paper. In cards 1 and 3, Fig. 63, for instance, the hook is beginning to form; the line ceases to go

up on the compression curve, and, if the compression had been a little higher, the line would have dropped as a hook. That hook means practically a cylinder condensation—not of the admitted steam, but of the compressed steam. The compression has been so high that the temperature of the steam is higher than that of the cylinder, and the steam begins to condense. In order to prove that, Professor Dwelshauvers proceeded to run the engine as an air compressor, everything else remaining unchanged, and the engine being driven by an electric motor; he got the lower curve shown, and no hook was produced. The moment steam was introduced, the hook appeared, and he concluded that the loss in the high compression is due to the condensation of the compressed steam exactly like the condensation of live steam.

Professor Jacobus.—Professor Kingsbury states that the mean calorimeter temperature of 259.7 degrees Fahr. corresponds to 1.6 per cent. of moisture in the steam. His tests were made at 70 pounds gauge pressure. This temperature does not correspond to 1.6 per cent. of moisture, but to slightly less than 1 per cent., provided the temperature given has been corrected for the radiation of the calorimeter, and for any error due to not heating the stem of the calorimeter thermometer. On the other hand, if no corrections have been made for radiation and in the thermometer reading, there will be a greater discrepancy involved than that which exists between his figures and that obtained on the as sumption that 259.7 degrees Fahr. is the corrected temperature.

I wish to ask Professor Kingsbury whether the corrections just specified have been made in the temperature reading of 259.7 degrees Fahr. which he gives; and to point out that, if such is not the case, the steam used in his experiments was much more nearly dry than he states in his paper.

Mr. J. E. Johnson, Jr.—I should like to ask in connection with these experiments if there are any data to be had on the effect of varying the surface of the clearance, leaving its volume the same.

We have now some data bearing on the effect of varying clearance, and that is one of the many elements affecting steam-engine economy which it is possible to determine with a reasonable degree of accuracy by calculation; while direct experiments varying clearance volume, without varying other almost equally important factors, especially compression, are, as Professor Kings-

bury's paper shows, practically impossible. Accurate quantitative data on the effect of clearance surface, on the other hand, are practically non-existent, and are of the utmost importance because a variation in that element probably affects economy more seriously than a variation in clearance volume.

It is also to be noted that tests with every other element constant and only the surface varied are a very simple matter.

It is only necessary to start with a relatively large clearance (obtained by recessing the cylinder head, or in some similar manner) with a perfectly plain surface and then, keeping the volume the same, make a corrugated head with a known increase in the amount of surface.

Tests made in this or some similar manner with the same kind of surface in each case, and especially a series of tests with different kinds of surface in the different sets but the same kind throughout each set of the series, would be of almost inestimable value.

If such a series included one with a surface which imitated as closely as possible the surface of the cylinder walls where polished by the piston as well as those representative of the surface of the heads, the results would, I believe, receive a very warm welcome from all designing steam engineers, and would certainly supply data by the aid of which the economy of a given engine could be determined by calculation much more accurately than is now possible.

In regard to the cards which Mr. Suplee has shown, in connection with varying compression, it is just as well to call attention to the fact that, while we get the "hook" in one case and do not in the other, the condensation which the hook represents takes place just the same with the lower compression, but is delayed until after admission occurs, and therefore is made good by live steam, and so does not get a chance to show.

Results of experiments on this subject are to be handled with extreme care. Professor Dwelshauvers-Dery published the results of a series of such experiments in "Power" a few years ago with some calculations based thereon, which, owing to the method by which the results were deduced, pointed to an utterly erroneous conclusion. Mr. Isherwood pointed this out afterwards, but his lucid explanation did not create, apparently, as deep an impression as it should have.

Mr. Suplee.—Of course, when the lead is increased a little and

the live steam let in, the hook on the compression curve disappears, the card looks better, and one feels better about it, but the steam has been lost all the same.

Mr. W. F. M. Goss.—I did not receive Professor Kingsbury's paper until after I had reached New York, and for this reason I am unable to present the results of certain tests made under my direction several years ago upon a plan precisely similar to that employed by Professor Kingsbury. My engine, however, was larger than that upon which he experimented, being of 35 horse-power and having a cylinder approximately 8 x 16 inches. The results of my experiments, as I now recall them, were substantially in accord with those presented by Professor Kingsbury; that is, wide differences in clearance did not materially affect the steam consumption. In my experiments, however, the piston displacement was so great in proportion to the capacity of the air port connecting the dead end of the cylinder with the atmosphere, that the work done upon the air resulted in the development of considerable heat, sufficient, as it seemed to me, to materially warm the walls of the cylinder. The difficulty was one which could not easily be overcome. Its existence, and the occurrence of certain inconsistencies which appeared in the data, cast some doubt upon the value of the results, and the outcome of the whole series was judged to be inconclusive.

We are now working upon the clearance problem by methods which seem to me to offer very great promise of success. We have a 16 x 24 inch Corliss engine, fitted with a disk crank, in which we have arranged holes for the crank pin at varying distances from the centre of the shaft, so that the stroke of the engine may be varied, with the result that the cylinder clearance will be kept substantially the same for both ends of the cylinder, while being varied from 4 to 22 per cent. I should add that the clearance problem is one of many variables; if, for purposes of experimentation, clearance is varied, all other things, such as cut-off, or possibly the power developed, and the compression must remain constant. But these latter factors are as important in their effect upon the economy of the engine as clearance itself, hence a complete solution of the matter requires a long list of tests in series, there being at least one series in which each of these variable factors shall appear in its turn as the only variable. Our laboratory has been engaged upon a plan of this sort for two years past, but the data accumulated are not enough to warrant general conclusions.

*Professor Kingsbury.**—In the experimental results submitted by Mr. Longwell it appears to me that the marked differences in the steam consumption of the two engines at very small loads is largely due to the well-known difference in the amounts of compression in the types of engine compared, the single-valve engine having high compression at low loads, and the Corliss engine little or none; and that no definite conclusion with regard to the effect of the difference in the clearance volumes, aside from compression, can be drawn from the comparison of the tests. Nevertheless, it seems quite possible that Mr. Longwell is right in his belief that a small amount of clearance may be beneficial, in certain cases, for purely thermodynamic reasons. It was one of the objects of our experiments to investigate this point, but, as already stated, we did not succeed in covering the desired range of loads and clearances.

With regard to the question raised by Professor Jacobus, I would say that no corrections were made for radiation or conduction for the throttling calorimeter; the ordinary formula for determination of the per cent. of moisture was used. The purpose in determining the moisture was rather to have assurance of its constancy than to find the exact amount, since no correction for moisture was made in stating the water-rate of the engine; and the per cent. of moisture is shown to vary only slightly. I may add that the calorimeter was wrapped with felt, the thermometer being inserted through a rubber cork and exposed directly to the superheated steam, which escaped at atmospheric pressure.

Professor Goss' plan for varying the clearance by varying the stroke of the engine would, it appears to me, introduce complexities quite as undesirable as those existing in our experiments; it would be difficult to deduce general laws from experiments made under such conditions. This method of varying the clearance was considered, among others, in planning our experiments, but was rejected, partly from the above consideration, partly because it would necessitate rebuilding the crank end of the engine.

Mr. Johnson's interesting suggestion as to the desirability of tests with constant volume and varying area of clearance is one which, it is to be hoped, may be carried out by some investigator. I do not, however, agree with him in thinking that we have at

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* Author's Closure, under the Rules.

present any very exact knowledge of the effect of clearance, either from theory or from experiment. There is very little information in print regarding experiments with varied clearance; much more work, like that of Dwelshauvers-Dery, has been done with constant clearance, and compression varying.

No. 923.*

THE HEAT-ENGINE PROBLEM. †

BY CHARLES E. LUCKE, NEW YORK.
(Non-Member.)
AND PRESENTED BY R. H. FERNALD.
(Associate Member.)

1. A MATHEMATICAL analysis of the different cycles of variation of state through which a mass of gas may pass can give no more than a provisional idea of the value of those cycles for converting the energy of heat into useful power. Such an analysis must presuppose certain ideal conditions that may or may not be possible in practice, and though mathematically we may find that one cycle should convert more of the heat supplied into work than any other, there may be difficulties in the way of practically getting this result. It may happen, for example, that a very complicated large or heavy machine is necessary, or that the required changes of state in the gas cannot be carried out at all, or, perhaps, not fast enough to be useful in a prime mover.

In the general study, then, of the heat-engine problem, we must add to the analytic cyclic discussion a careful consideration of a number of practical questions, the results of which, when allied with the mathematical analysis, will permit of a

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* Presented at the New York meeting (December, 1901) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For further discussion on the same topic consult the *Transactions* as follows:

No. 843, vol xxi., p. 396: "An Efficiency Test of a One Hundred and Twenty-five Horse-power Gas Engine." C. H. Robertson.

No. 861, vol. xxi., p. 961: "The Gas-engine Hot Tube as an Ignition-timing Device." Wm. T. Magruder.

No. 875, vol. xxii., p. 152: "Efficiency of a Gas Engine as Modified by Point of Ignition." C. V. Kerr.

No. 879, vol. xxii., p. 312: "A New Principle in Gas-engine Design." C. E. Sargent.

No. 895, vol. xxii., p. 612: "Efficiency Tests of a One Hundred and Twenty-five Horse-power Gas Engine." C. H. Robertson.

logical selection of the proper cycle to which we should devote our executive energies; their goal is the production of that prime mover whose source of energy shall be heat, whose medium of transformation of this heat into work a perfect gas, and which shall call for the simplest machine, giving the greatest power in the smallest space with the least metal and under the most favorable circumstances.

2. Every cycle available for transforming heat energy into mechanical energy by the moving of a part against a resistance, must include as one of its phases the heating of the gas in some particular way peculiar to that cycle. This giving of heat energy to the transforming gas presupposes a source of heat which in practice must be a fire. The heat of a fire may be imparted to a mass of gas in three ways:

I. The fire may be placed on one side of a wall through which the heat must pass to the mass of gas on the other side; this may be termed external heating.

II. The fire may be caused to heat a solid mass, which is afterward shut off from the fire and brought into contact with the mass of gas; this is a combination of external and internal heating.

III. The fire may be enclosed and maintained by the mass of gas itself; in this case the gas must be, at least in part, air which will furnish oxygen for this internal combustion.

3. Any system which depends on the heating of the gas by contact with solid matter at a high temperature, must necessarily be slow in operation and involve large masses of gas. For the transfer of heat, the source must be hotter than the receiving mass, and a difference of temperature, for a given rate of transfer sufficiently high to be of practical value, must be greater than the medium of transfer can stand without injury. Consider how hot the walls of a chamber would have tobe ot heat a mass of gas as rapidly as is done in the gas engine, and the point made above will be clear. Nevertheless, engines with this kind of heating have been built, but, admirable as some of them have been in conception, they have proved failures as prime movers in competition with others because of the points noted. The engines of Ericsson, Rankine, and the Stirlings are all included in this class, with results that are well known. Ericsson's large engine of 300 horse-power showed a mean effective pressure of about 2 pounds per square inch with a piston area

of 600 square feet. The only machine now working with this external heating is the one known as Rider-Ericsson, used in small sizes only for the slow pumping of water.

4. Nothing that this system can do will compare with what may be derived from the use of the internal-combustion method of heating. This internal-combustion heating of a mass of gas will permit of a heating as rapid as we choose, and to any temperature up to a certain maximum. If all the air supplied has its oxygen converted with the fuel to CO_2, H_2O, etc., there being no excess of either oxygen or fuel, then the mass of gas which, it is true, has changed in chemical composition, but not materially in physical properties, has received the maximum amount of heat obtainable from the combustion of the fuel used. If only a part of the air support combustion and the products be diluted with unused air or by steam, etc., then any desired temperature between the original temperature of the gases and the maximum may be obtained. The problem of heating gases by an internally maintained fire is difficult, compared with the other method of external heating, and this may account for its later application. We might say in brief that externally heating a gas is thermally bad but easily done, internally heating the gas, thermally good but not so easy to do.

5. Heating working gases by internal combustion has been done with coal, oil, and gas. The methods used might be tabulated briefly.

I. With coal:

(*a*) Air is passed through a coal fire with or without a grate. Cayley, Shaw, and Genty.

(*b*) A coal fire is moved through an enclosed mass of air. Lord.

II. With liquid fuel not previously vaporized:

(*a*) The enclosed air acts as a quiet atmosphere supporting the combustion of a jet of oil flame. Diesel.

(*b*) The air is caused to move past a burner, and in passing supports combustion, the heated products passing on. Wilcox, Brayton, Nordberg, and Shadall.

(*c*) Oil is thrown into a hot chamber, there vaporized, and brought into contact with the air, the proportions being so maintained as to make the resulting gaseous mixture explosive.

Combustion is of the self-propagated sort. Hornsby, Mietz & Weiss, and Capitaine.

III. With gas or previously vaporized oil:

(*a*) An enclosed air atmosphere supports a quiet jet of gas flame. Diesel and Gibbs.

(*b*) Air in motion passes a fixed gas flame as in most atmospheric engines. Wilcox, Weiss, and Otto atmospheric.

(*c*) Air mixed with gas in explosive proportions is caused to pass a point where the combustion is localized. Brayton, Schmid, Beckfeld, and Reeve.

(*d*) Air mixed with gas in explosive proportions is enclosed in a chamber, and while at rest burned by self-propagation, after inflammation was provoked by a local ignition. Otto, Priestman, Nash, Westinghouse, and in fact nearly all existing internal-combustion engines.

The above classification leads directly to the broad division of internal-combustion engines into two great classes, the explosive and non-explosive. The term "explosive" we shall apply to all those engines in which a mass of gaseous mixture at rest is ignited at one point, and the whole burned by self-propagation. The other term, "non-explosive," we shall apply to those engines in which the gases are in motion and in that motion pass a point where combustion is localized, and are there heated in the passing. To complete our terminology, we add the expressions "intermittent non-explosive," to those machines in which the combustion is periodically interrupted at the cylinder end as in Diesel's, and "continuous non-explosive" to those in which the combustion is maintained in a chamber, and the hot gases used as required, as in Reeves, Schmid, and Beckfeld.

We have, then, explosive engines; non-explosive engines with intermittent combustion, or continuous combustion as the different kinds of internal-combustion engines.

6. The explosive engine as developed and perfected, chiefly by Dr. Otto, holds the field to-day, and its very general use has brought out its merits and demerits. It has been, and is to-day, the subject of many researches and experiments, all tending to perfect it by the discovery of its faults. All this has resulted in its present position, which might be summed up as follows:

It is extremely simple in construction, having comparatively few working parts.

The thermal changes of heating and expansion are all performed in the same place, on a quiet mass of gas, and nothing but the gas is heated.

The best engines—those of rational design—do not differ much in construction and results, and this brings out an important point—that in the handling of a mass of gas to be exploded, we accept a certain inflexibility from which we cannot escape.

7. As a machine, it cannot compare with the steam engine. It is not easy to start, and cannot be worked at widely variable speeds; its governing is bad, the speed varying at different points of the stroke, but adding up to a fairly constant total number of revolutions per minute; it has no margin of power and carries an ignition system that once deranged stops the machine; it is non-reversible; it has a low mean effective pressure for high-pressure range, hence is heavy; it can use only one kind of fuel, and that gas, and whether this be produced from oil or coal, it must, nevertheless, be produced outside the natural gas regions. It cannot, and never will be, able to use crude, unrefined oils directly; it operates under only one fixed cycle.

8. About as much can be said for the explosive type as against it. It has occupied nearly all workers in the internal-combustion field for the past thirty years, and the success attained continues to draw to the problem large numbers of men and an immense amount of capital, and these, working together, must do much for this type in the future. But while this good work goes on, there is no reason why the other types of internal-combustion engines should not receive their share of attention. Some have been built and many proposed; some were successful and some failures; but a careful study of what has been done successfully and the cause of failure of the unsuccessful engines would, if no more, show clearly the possibilities of this type. If the difficulties are clearly set forth, the solution will be the easier, and if in the study of the difficulties the solution appears, so much the better.

Of the successful engines of the non-explosive type, there may be mentioned two that easily head the list, the old Brayton and the modern Diesel, and the results obtained from these machines are certainly encouraging. However, before entering into a discussion of the various non-explosive machines, it would be well to make sure of our theoretical grounds.

9. The different cycles of operation that might be performed

on a mass of gas are infinite, but there is a limited number which are striking and simple. These are given below.

Let Fig. 67 be a pressure-volume diagram for the Cycle I.

Then we have:

From *B* to *C*. Addition of heat isometrically from atmospheric pressure.

From *C* to *D*. Adiabatic expansion to atmospheric pressure.

From *D* to *B*. Cooling at atmospheric pressure.

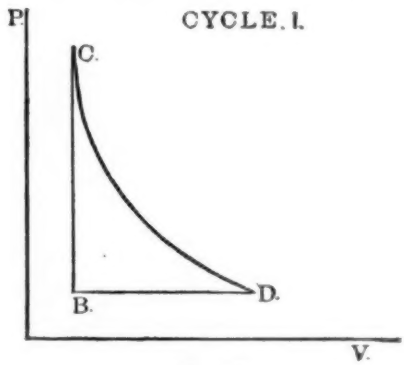

Fig. 67.

In Fig. 68 we have for Cycle I*A*.:

From *B* to *C*. Addition of heat isometrically from atmospheric pressure.

From *C* to *D*. Adiabatic expansion to a point above atmospheric pressure.

From *D* to *E*. Cooling isometrically to atmospheric pressure.

From *E* to *B*. Cooling at atmospheric pressure.

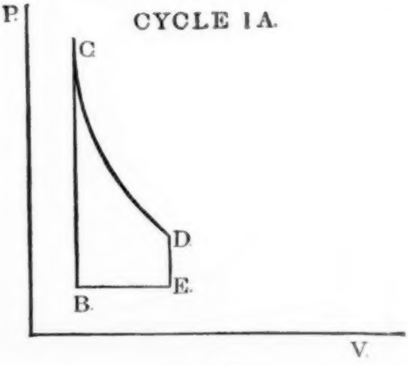

Fig. 68.

In Fig. 69 we have for Cycle I*B*.:

From *B* to *C*. Addition of heat isometrically from atmospheric pressure.

From *C* to *D*. Adiabatic expansion to below atmospheric pressure.

From *D* to *E*. Cooling isothermally to atmospheric pressure.

From *E* to *B*. Cooling at atmospheric pressure.

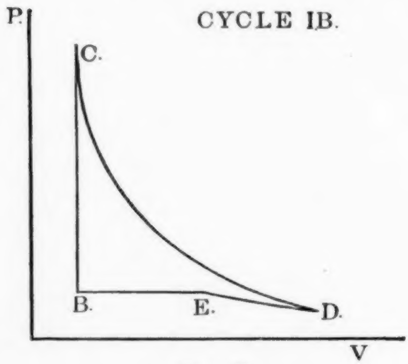

Fig. 69.

In Fig. 70 we have for Cycle I*C*.:

From *B* to *C*. Addition of heat isothermally from atmospheric pressure.

From *C* to *D*. Adiabatic expansion to a pressure below atmospheric such that we get,

From *D* to *B*. Cooling isothermally to the original volume and atmospheric pressure.

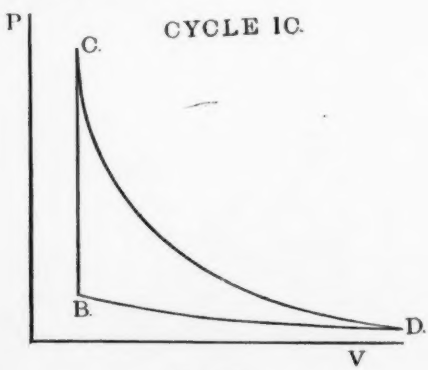

Fig. 70.

In Fig. 71 we have for Cycle II:

From A to B. Adiabatic compression from atmospheric pressure.

From B to C. Addition of heat isometrically.

From C to D. Adiabatic expansion to atmospheric pressure.

From D to A. Cooling at atmospheric pressure.

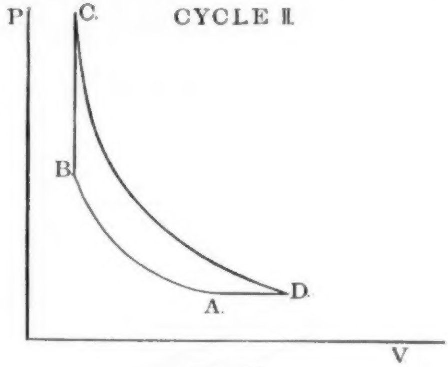

FIG. 71.

In Fig. 72 we have for Cycle IIA.:

From A to B. Adiabatic compression from atmospheric pressure.

From B to C. Addition of heat isometrically.

From C to D. Adiabatic expansion to a pressure above atmospheric.

From D to E. Cooling isometrically to atmospheric pressure.

From E to A. Cooling at atmospheric pressure.

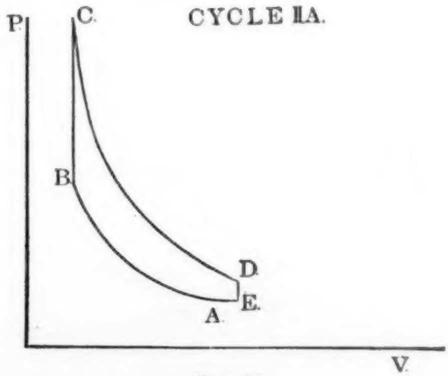

FIG. 72.

In Fig. 73 we have for Cycle II*B*.:

From *A* to *B*. Adiabatic compression from atmospheric pressure.

From *B* to *C*. Addition of heat isometrically.

From *C* to *D*. Adiabatic expansion to pressure below atmospheric.

From *D* to *E*. Cooling isothermally to atmospheric pressure.

From *E* to *A*. Cooling at atmospheric pressure.

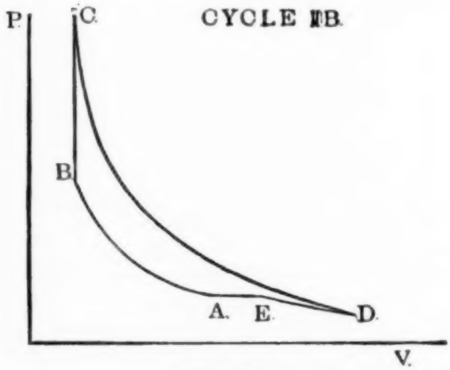

FIG. 73.

In Fig. 74 we have for Cycle II*C*.:

From *A* to *B*. Adiabatic compression from atmospheric pressure.

From *B* to *C*. Addition of heat isometrically.

From *C* to *D*. Adiabatic expansion to a pressure below atmospheric such that we get,

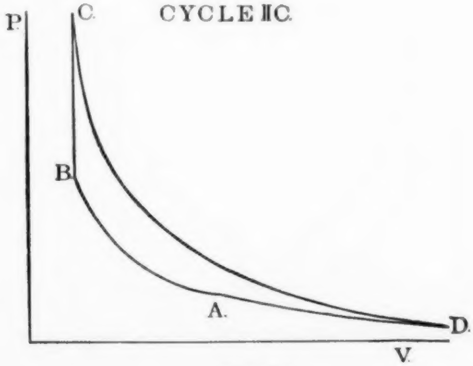

FIG. 74.

From D to A. Cooling isothermally to the original volume and atmospheric pressure.

In Fig. 75 we have for Cycle III:

From A to B. Adiabatic compression from atmospheric pressure.

From B to C. Addition of heat isopiestically.

From C to D. Adiabatic expansion to atmospheric pressure.

From D to A. Cooling at atmospheric pressure.

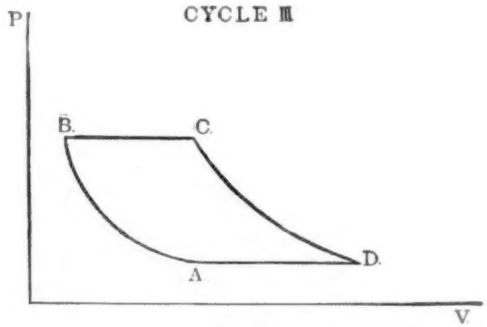

FIG. 75.

In Fig. 76 we have for Cycle IIIA.:

From A to B. Adiabatic compression from atmospheric pressure.

From B to C. Addition of heat isopiestically.

From C to D. Adiabatic expansion to a pressure above atmospheric.

From D to E. Cooling isometrically to atmospheric pressure.

From E to A. Cooling at atmospheric pressure.

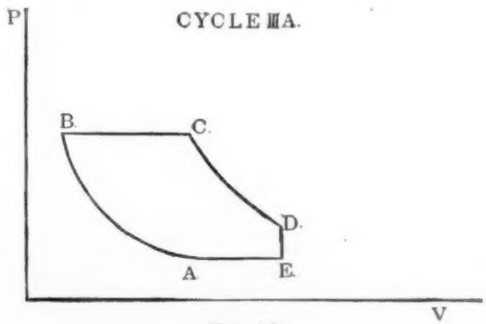

FIG. 76.

In Fig. 77 we have for Cycle III*B*.:

From *A* to *B*. Adiabatic compression from atmospheric pressure.

From *B* to *C*. Addition of heat isopiestically.

From *C* to *D*. Adiabatic expansion to a pressure below atmospheric.

From *D* to *E*. Cooling isothermally to atmospheric pressure.

From *E* to *A*. Cooling at atmospheric pressure.

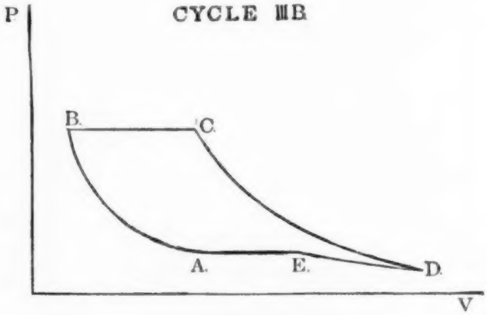

FIG. 77.

In Fig. 78 we have for Cycle III*C*.:

From *A* to *B*. Adiabatic compression from atmospheric pressure.

From *B* to *C*. Addition of heat isopiestically.

From *C* to *D*. Adiabatic expansion to a pressure below atmospheric such that we get.

From *D* to *A*. Cooling isothermally to the original volume and atmospheric pressure.

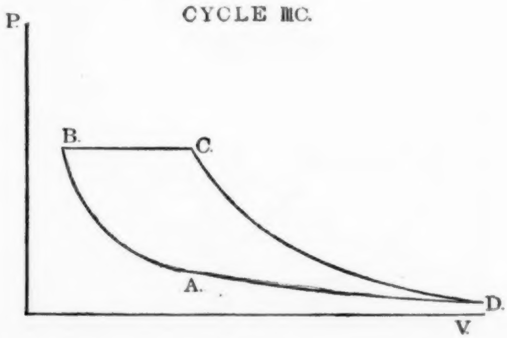

FIG. 78.

In Fig. 79 we have for Cycle IV.:

From A to B. Adiabatic compression from atmospheric pressure.

From B to C. Addition of heat isothermally.

From C to D. Adiabatic expansion to atmospheric pressure.

From E to A. Cooling at atmospheric pressure.

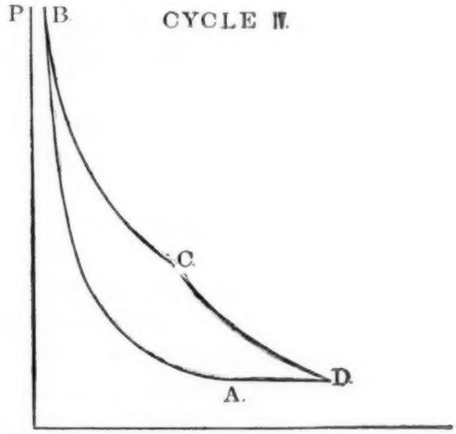

FIG. 79.

In Fig. 80 we have for Cycle IVA.:

From A to B. Adiabatic compression from atmospheric pressure.

From B to C. Addition of heat isothermally.

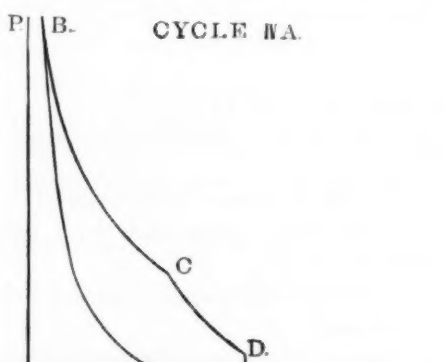

FIG. 80.

From C to D. Adiabatic expansion to a pressure above atmospheric.

From D to E. Cooling isometrically to atmospheric pressure.

From E to A. Cooling at atmospheric pressure.

In Fig. 81 we have for Cycle IVB.:

From A to B. Adiabatic compression from atmospheric pressure.

From B to C. Addition of heat isothermally.

From C to D. Adiabatic expansion to a pressure below atmospheric.

From D to E. Cooling isothermally to atmospheric pressure.

From E to A. Cooling at atmospheric pressure.

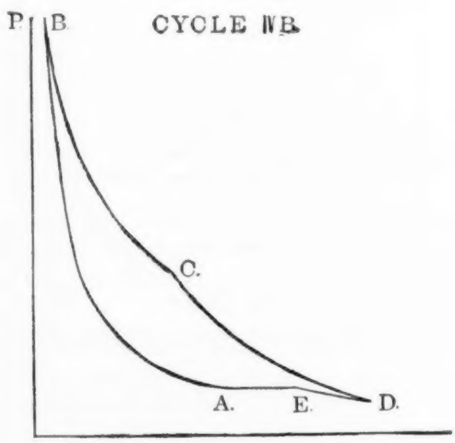

FIG. 81.

In Fig. 82 we have for Cycle IVC.:

From A to B. Adiabatic compression from atmospheric pressure.

From B to C. Addition of heat isothermally.

From C to D. Adiabatic expansion to a pressure below atmospheric such that we get,

From D to A. Cooling isothermally to the original volume and atmospheric pressure.

Besides these there are various atmospheric cycles—sometimes called vacuum cycles—in which the first step is the heating of the entering charge at atmospheric pressure. Because of their slight importance they are here omitted.

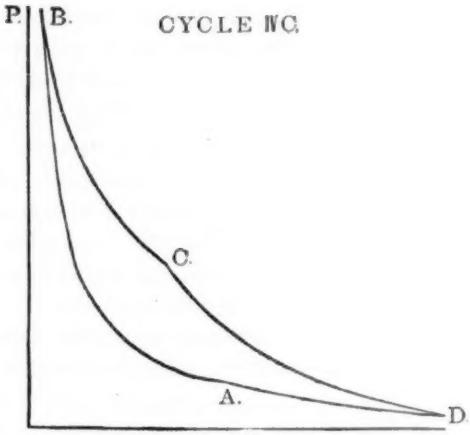

FIG. 82.

10. A very careful mathematical analysis* of all these cycles leads to these conclusions:

(*A*) Cycle I. and its variations, by reason of its poor showing in efficiency and mean effective pressure as compared with the previous-compression Cycle II., must be set aside.

(*B*) The atmospheric cycles, by reason of their low mean effective pressure and consequent large volume range, are useless for power purposes as compared with the other cycles.

(*C*) This leaves as the only cycles worthy of application, II., III., IV., and their variations.

(*D*) Of the last mentioned, there are three which are peculiar, and these are: Cycle II*A*., Otto, heating and cooling the gas at constant volume; Cycle III., Brayton, heating and cooling the gas at constant pressure, and Cycle IV*C*., Carnot, heating and cooling the gas at constant temperature.

All these have the same efficiency for the same compression, and should, consequently, with the same heat supplied, do the same work.

The efficiency of each is given by

$$E = 1 - \left(\frac{V_b}{V_a}\right)^{\gamma - 1},$$

where V_a is the volume before compression,
V_b " " after "
γ " ratio of specific heats, and for air, $\gamma = 1.406$.

* Columbia School of Mines *Quarterly*, Nos. 1, 2, 3, vol. xxii., 1901.

(*E*) The other cycles, II., II*B*. and *C*.; III*A*. and *B*.; IV., IV*A*. and *B*., can easily be given their proper comparative position by remembering that each is a more or less complete expansion of one of the above three. For example, if in the Otto the expansion were carried to atmospheric pressure, the efficiency would be greater than for the Otto. Similarly with the Carnot, if the expansion were stopped at atmospheric pressure as was first suggested by Diesel, the resulting Cycle IV. would have an efficiency less than the Carnot, and hence less than either the Otto or Brayton cycles.

(*F*) The other variables entering have the values tabulated for each of the cycles adopted for comparison.

Given the { Same mass of gas, Same heat supplied after, Same compression.

There will result for

Cycle II*A*., Otto; " III. Brayton; " IV*C*. Carnot } Same work done, and hence same efficiency.

And, further,

	Lowest.	Intermediate.	Highest.
Maximum temperature	Carnot	Brayton	Otto
Pressure range	Brayton	Carnot	Otto
Volume range	Otto	Brayton	Carnot
Temperature range	Carnot	Brayton	Otto
Mean effective pressure	Carnot	Brayton	Otto
$\dfrac{\text{Pressure range}}{\text{Mean effective pressure}}$	Brayton	Carnot	Otto
Mean effective temperature	Carnot	Brayton	Otto

The relation of the Diesel to the Otto and Brayton is easily seen, if we remember it as an imperfect Carnot.

11. Some of these variables should be a maximum and some a minimum. For the maximum temperature the Carnot holds first place, but its impracticability yields the place to Brayton. Neither pressure range nor mean effective pressure is wanted by itself, but only the ratio between them, for it is to this ratio that the weight of the engine must be approximately proportional; here Brayton holds the most favorable place.

Volume range should be low, and here first place is held by the Otto. The mean effective temperature should be low, and the Brayton is exceeded only by the Carnot.

The low mean effective pressure of the Carnot, and all other

isothermal combustion cycles, is sufficient warrant for cutting them out of consideration in comparison with the Cycles II., III., and their variations.

We have thus arrived at the conclusion that, theoretically, the last-named cycles only are worthy of further consideration. Of these the Brayton, III., holds a most favorable position, being surpassed by the Otto only in the position of volume range.

12. In the above, the hypothesis that heat could be added to the gas has been assumed, and no account taken of the means of so doing, but this point needs consideration. If heat be added through walls from a source of known supply, of which we can control and use as much or as little as we please, there will be no alteration in the formulæ or results of the analytical comparison; but the internal-combustion method of heating presents some new questions for solution. First, the air and fuel become carbonic acid, steam, etc., and as to what value of the specific heat should be used, who can say? Second, the chemical change is accompanied by an intrinsic volume change. Third, there may be reasons why the fuel should give out more heat when burned in one way than when burned in another.

13. The only ways of heating by internal combustion that are worth anything for power are the constant volume and constant-pressure methods. On theoretical grounds, we have no reason for saying that, for any particular system of combustion, more heat can be developed one way than the other. The evidence that heat has been added to a mass of gas in an engine is, for the two cases: (A) an increase of pressure, and (B) an increase of volume. This pressure increase on the one hand and volume increase on the other we can readily observe by indicators, and the results of these observations on a large number of indicator cards show that the increase is not what it should be if all the calorific value of the fuel had developed.

In short, there is in practice abundant evidence of heat supression, and whether this be due to radiation, conduction, dissociation or an increase of specific heat, or to an actual non-production of heat is unknown. What we do know and can assert is that the effects on pressure and volume are such as they would be if only a part of the heat supposed to be generated had appeared. The result might be worked up to give a new value to the heating power of the fuel, to be called its *effective* calorific value, or a

new value given to the specific heat, to be called the *effective* specific heat of the process.

14. For constant-volume combustion we have, for H_1, the British thermal units per pound of mixture,

$$\frac{p_2}{p_1} = \frac{T_2}{T_1} = 1 + \frac{H_1}{C_v\ T_1},$$

where p_1 = pressure before compression.
T_1 = temperature before combustion.
p_2 = pressure after combustion.
T_2 = temperature after combustion.
C_v = specific heat at constant volume.

This ratio in the general run of gas engines will average about 3.5. In some cases it may reach 4, but I know of no case where it has reached 5. Some values are given below:

Engine.	$\frac{p_2}{p_1}$	Remarks.
Westinghouse	3	On Gas
Otto	4.0	N. Y. Gas
Hornsby Ackroyd	3.5	Kerosene
Nash	4	N. Y. Gas
Clerk	4	Glasgow Gas
Crossley	3	Dowson Gas
Priestman	3.5	Kerosene
Crossley oil	3.5	Kerosene

A general statement, very nearly true, would give these pressure and temperature ratios about 50 per cent. of what the usual values of H_1 and C_v would produce. These figures, while not strictly true for any one case, give a fair average value.

15. The other system of combustion—that at constant pressure—may be observed in the same way. The only indicator card I have of this type of engine was taken from a Brayton oil engine with its smoky fire. The volume ratio, in this case, is quite well given by the relative lengths of the delivery line of the compressor and the admission line of the power cylinder, and is given by

$$\frac{v_2}{v_1} = 3.2.$$

Let us see how this compares with the pressure ratios given. Theoretically,

$$\frac{v_2}{v_1} = \frac{T_2}{T_1} = 1 + \frac{H_1}{C_p\ T_1},$$

where C_p is the specific heat at constant pressure and the other symbols are as heretofore; combining this with the similar one for the other type we get

$$\frac{H_1}{T_1} = C_v\left(\frac{p_2}{p_1} - 1\right) = C_p\left(\frac{v_2}{v_1} - 1\right),$$

or $$\frac{p_2}{p_1} = 1 + \gamma\left(\frac{v_2}{v^1} - 1\right).$$ Take $\gamma = 1.4$; and

$$\frac{p_2}{p_1} = 1.4\frac{v_2}{v^1} - .4.$$

By substitution, when

$$\frac{v_2}{v_1} = 1, \quad \text{we get} \quad \frac{p_2}{p_1} = 1.$$

$$\frac{v_2}{v_1} = 2, \quad \text{"} \quad \text{"} \quad \frac{p_2}{p_1} = 2.4.$$

$$\frac{v_2}{v_1} = 3, \quad \text{"} \quad \text{"} \quad \frac{p_2}{p_1} = 3.8.$$

$$\frac{v_2}{v_1} = 3.2, \quad \text{"} \quad \text{"} \quad \frac{p_2}{p_1} = 4.44.$$

16. This shows that when a Brayton engine gives a volume ratio in combustion of 3.2, there is evidence of as much heat as would cause a pressure ratio of 4.44 in an explosion engine; hence it would seem that, for the combustion process alone, the Brayton engine, even with its poor fire, was giving evidence of as much heat as the very best explosion engine, and more than can most of them. This point is very striking, and, in order to verify or disprove it, a large mass of data is necessary, which can be collected only after considerable time.

The above point bears strongly on the formulæ of cyclic comparison. The analysis showed that the Otto and Brayton cycles must have the same efficiency for the same heat added; but, if one, by reason of its system of combustion, can take from the fuel more heat than the other, then that one must have the higher efficiency.

17. All non-explosive internal-combustion engines, except the atmospheric types, must provide for three stages: first, the supplying of working gases, which are derived from air and fuel, hence, we need an air and a fuel supply; second, the causing of

the combination of the fuel and air in combustion to raise their temperature, and thereby vary either pressure or volume of the gas, as we desire; third, the utilization of the hot gases thus produced to actuate a mechanism by the action of expanding gas on a moving part.

I. The air and fuel supply may be accomplished in any of the ways known to and accepted by engineers; the results cannot vary much with changes in design of this part, since compressors and pumps are well-known machines.

II. The burning of the fuel in the air supplied offers what is probably the most difficult problem for solution. Its difficulty is attested by the variety of the means proposed and the indifferent success of those that have been tried. When solid fuel was used, as in Cayley's engine, no means, without great complication of parts, were found adequate to cope with the smoke, dust, and distillation of gas from the coal. With liquid fuel, Brayton was troubled with soot, and those burners which have burned clean required a large excess of air. With gas, Brayton also failed, and he was not alone, as no adequate system of burning gas, when enclosed and under pressure, had then been proposed, the trouble being not so much in getting a burner to work under specified conditions, as to get one that would work under wide and sudden variations of feed and pressure.

III. The utilization of the hot gases has been successfully tried in cylinders, and rotary machines have been proposed, including the turbine; though none have appeared on the market, it is inconceivable that there can be any serious trouble to be anticipated in such utilization. The reason of the general failure of the machines proposed is probably the difficulty noted above, for gases at high temperature are used every day in exploding engines with the greatest ease. All of these non-explosive engines may work under any one of several cycles, depending on the relation between the last two processes—the amount of heating compared with the amount of expansion permitted. Here is an important point, for by a simple control of the above relations, by passing air around the fire and varying the cut-off to the power cylinder, we can vary the cycle, hence the work output; thus an engine equipped with means to do this would be able to work at all loads equally well, and be able to pull up to a temporary overload, just as do steam engines. This great elasticity of action is beyond comparison with the

rigidity of the explosive engine. Moreover, the question of available fuel again comes up; anything that will burn may be used, and with it a working elasticity obtained – two desirable results.

Before we examine the details entering into engine construction, let us look at some of the complete machines that have been proposed for carrying out the system, dividing our study according to the fuel used, taking up, first, coal-burning; second, oil-burning; and third, gas-burning engines.

Coal-burning Engines.

18. The first working engine of this class was Cayley's furnace-gas engine. The air was forced into the fire-box, where a coal fire was maintained, and the hot gases used in a cylinder. This engine worked on what has been called the Brayton cycle. Rankine says of it: "The cylinder, piston, and valves were found to be so rapidly destroyed by the intense heat and dust from the fuel that no attempt was made to bring it into use."

In the United States, Philander Shaw proposed the engine of Figs. 83 and 84 in 1861. Air from a pump cylinder passes more or less through a coal fire, becoming heated in its conversion, and finally with increased volume working in a larger power cylinder. The fire-box is provided with a grate, c, and is lined with brick J (Fig. 83), fuel is fed through H (Fig. 84), and is moved by a piston head g. The furnace has openings, a^1, below the grate, and others, a^2, above the fuel. Two single-acting cylinders are connected at 180 degrees to one shaft. Each cylinder is in two parts: the upper, A, is finished to a fit with piston D; the lower part, B, is left rough, as the lower part, F, of the piston does not touch it. The top of the piston has a trunk, C, which acts as an air-pump cylinder with the main cylinder casing. The motion of the air is indicated by the arrows, and the proportion that enters the fire-box above or below the fuel is controlled by a valve r (Fig. 83). The heated air and gaseous products of combustion pass into the cylinder through valve p, and the exhaust passes out through a heater for incoming compressed air. A little flange, s, is placed to catch dust and a groove, v, for oil.

19. All parts where radiation is likely to occur are jacketed by the incoming air. The working part of the piston fits loosely, and at a point just above the highest position of its bottom is an

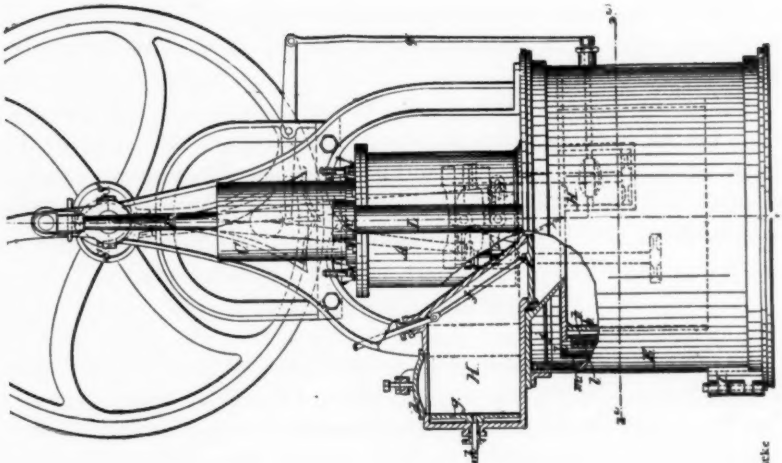

FIG. 84.

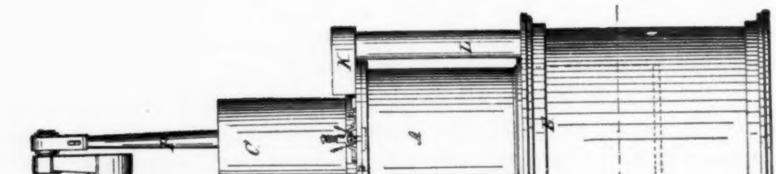

FIG. 83.

annular space kept filled with cool air to prevent overheating of the working faces. Governing may be made two-fold: first, the amount of heat added to the air can be regulated by sending more or less through the fire; and, second, the power may be directly controlled by the main cylinder cut-off. The air receives heat really from one source, though in two places—the one source being the fire, and the two places the exhaust-warmed pre-heater, or regenerator, and the fire-box. A hand pump is proposed to raise the internal pressure for starting.

20. The engine proposed by Henry Messer in 1863 is shown in Figs. 85–87. The air pump is double-acting, and the power

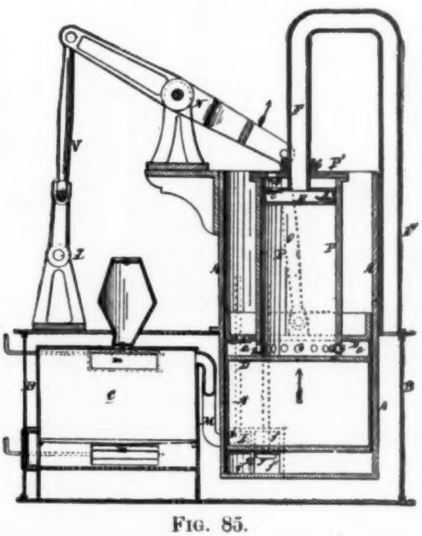

FIG. 85.

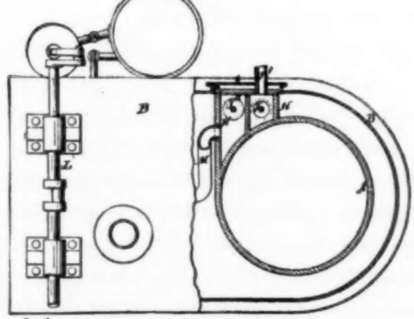

FIG. 86.

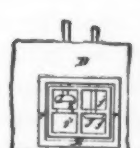

FIG. 87.

cylinder single-acting, hence there are two stages: 1. On the down-stroke air is compressed and heated at decreasing volume; 2. On the up stroke the air, previously compressed and heated, is sent through the fire and thence to the working cylinder. When the up-stroke begins, the high-pressure gases in the reservoir begin to expand at the same time that the air in the pump begins to increase in pressure, and, finally, when the increasing pressure in the pump equals the decreasing pressure in the receiver the second cylinderful of air becomes available. In its passage the air may take up enough heat to maintain p constant, T constant, or neither; it is impossible to say, hence

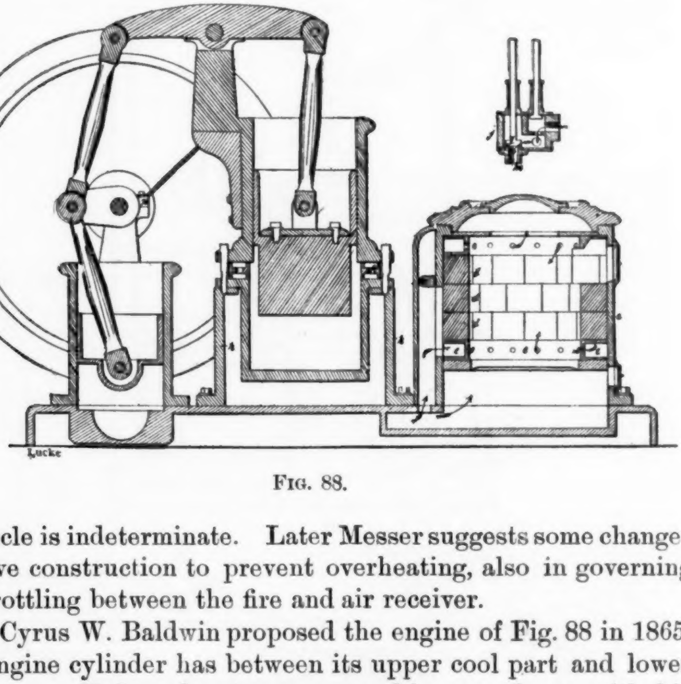

FIG. 88.

the cycle is indeterminate. Later Messer suggests some changes in valve construction to prevent overheating, also in governing by throttling between the fire and air receiver.

21. Cyrus W. Baldwin proposed the engine of Fig. 88 in 1865. The engine cylinder has between its upper cool part and lower hot part an H-shaped water passage f in accordance with his belief that more trouble with overheated working faces will be caused by heat conducted through the metal cylinder walls than by contact with the hot gases. He provides for distilling gases from the coal fire by supplying an auxiliary fire beyond the main furnace. He says: "Part of the fuel in the large furnace is changed by the heat therein to volatile gases, which do not burn when generated, but will burn if, while they are hot, they are

brought into flame. To supply such a flame through which all the products of combustion from the large furnace must pass, a small furnace is supplied, and the results which follow its application are found in practice to be highly beneficial."

22. In the engine of L. A. L. Söderström, 1869, a radical change of arrangement is proposed, as shown in Fig. 89. The

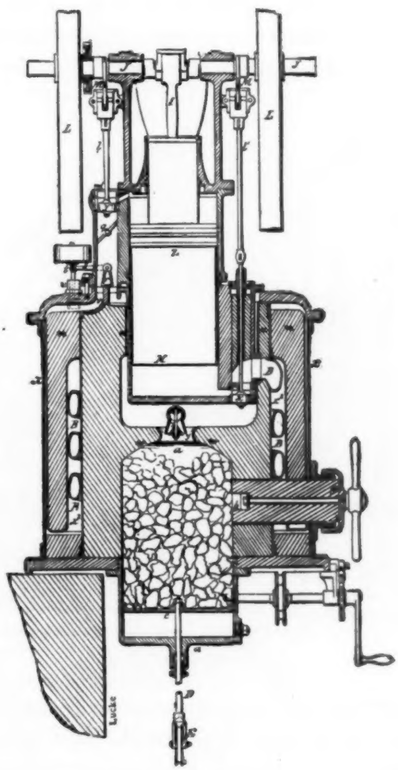

FIG. 89.

upper part of the cylinder acts as the compressor and sends air down and around the casing, the air passing the exhaust reheating coil *B*. After this reheating by contact with the exhaust coil the air is sent out through the opening *yx* on top of the fire at *a*, the top combustion helping to prevent coking and distillation, but adding trouble from dust and ash. Governing is effected by a split current and variable cut-off.

23. Thomas M. Fell in 1880 proposed a very interesting though complicated machine (Fig. 90). An air compressor, C^1, sends air through the pipe M^1 to the fire at A. Exhaust gases from the power cylinder A^1 are thrown first around the tubes D^1, and then around the water-cooled tubes E^1, and are returned by the pump B^1, through the tubes D^1, and back to the hot chamber T through the valve H^1. Accumulation of gases in the closed system is prevented by the blow-off G^1, arranged to maintain a constant pressure on the high-pressure side of the system. An attempt is made to keep a two-part system, one

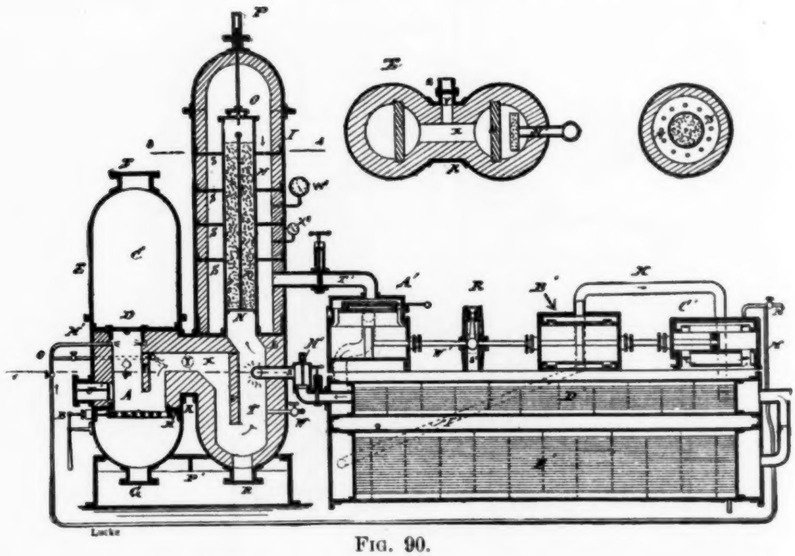

FIG. 90.

high-pressure heating, and the other low-pressure cooling. This system would probably give the results of Cycle III*C*., or one somewhat similar.

24. Hiram S. Maxim in 1884 proposed a machine as shown in Fig. 91. Air is drawn by the right-hand side of the piston from the space A^1, which in turn gets its supply from the atmosphere by a throttling slide T. This space A^1 has a diaphragm R so arranged that a partial vacuum will cause the slide valve N to by-pass air around the fire. In its normal operation, or when running slowly, most of the air passes through the fire and is heated. At the time the air is passing into the receiving chamber no air is entering the working side of the cylinder. Hence

the heating of the air during this stage must take place at decreasing volume and increasing pressure. When this is finished, the valve V opens and gases enter on the impelling side of the piston. The tendency now is to decrease pressure, but air in the space G^1 will pass the fire, tending to uphold pressure; hence there is a second heating at uncertain pressure, giving an indeterminate cycle.

25. Lucien Genty in 1893 proposed the engine of Figs. 92–94. This engine has the usual single-acting cylinder with elongated

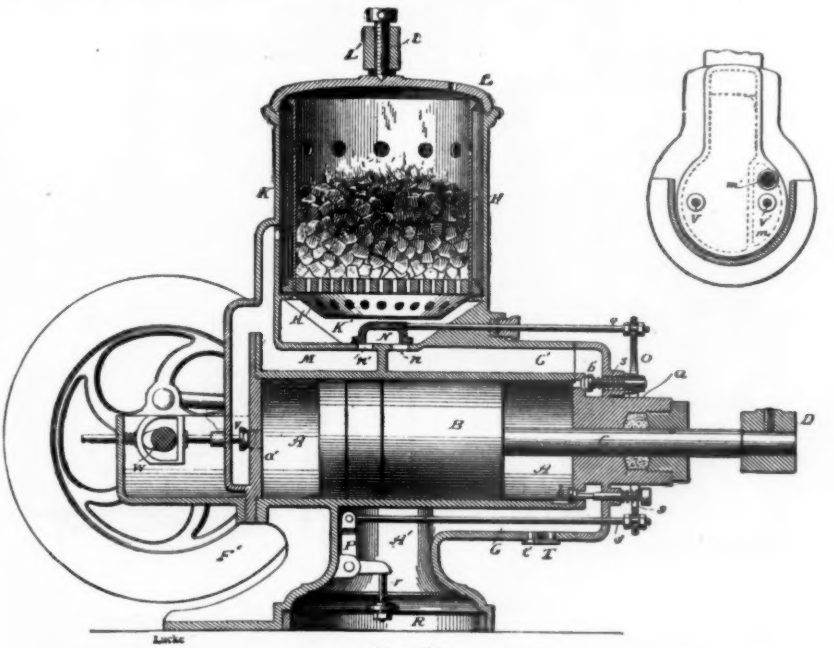

FIG. 91.

piston. Air is drawn from a chamber under the floor to obviate the noise of suction. The air thus received by the water-jacketed compressor 10 is sent through the valves 17 into the hollow bed 4, and thence past the ribbed-coil preheater, here to be warmed by the exhaust. The preheater is arranged to take up expansion, and exhaust gases are prevented from touching the metal by brick lining. The partly heated air enters admission valve 36 by pipe 35. Valve 36 is double balanced, and held to its seat by a helical spring, and is actuated by a cam on the horizontal shaft.

26. The valve gear is arranged to govern by varying the opening of valve 36. A weighted piston controller regulates the proportion of air admitted to the two passages 41 and 42 after passing the admission valve 36. Thus the method of governing is two-fold ; 1, by a variable cut-off to the power cylinder and combustion chamber, and 2, by means of keeping the pressure of the air admitted initially constant. Passage 42 leads above the fire and 41 below.

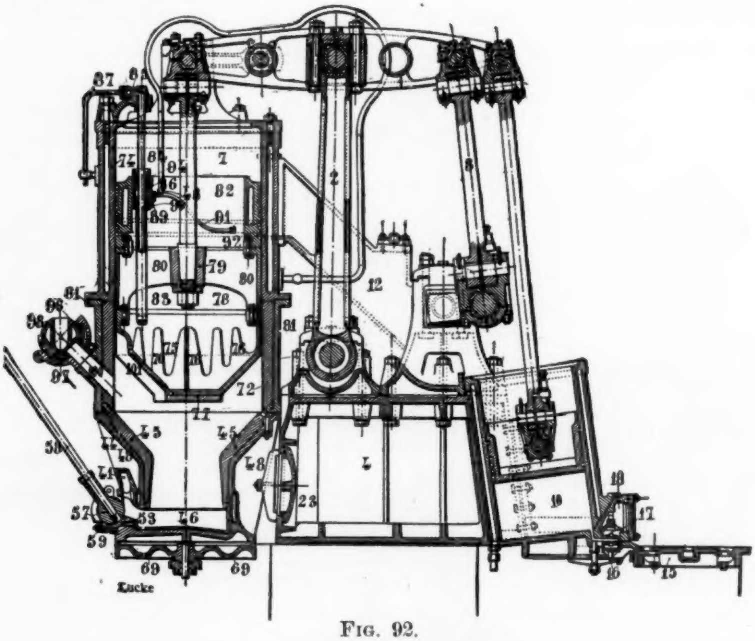

FIG. 92.

The combustion chamber is a cast-iron funnel lined with brick, enlarged at the bottom ; the coal is thus burned without a grate. The lower and hottest part has a water-jacket, 49. Means for charging and cleaning are provided, and a ball-and-socket swivel, 57, carries a stirrer, 58, which is removable. After passing the admission valve and reaching the fire, the air is first heated and afterwards expanded in the presence of the fire under the piston. The motor cylinder is of two parts ; the lower, 72, is lined with fire clay, the upper, 74, is bored true and water-jacketed. The lower part of the piston has air-cooling ribs, 76, and the rod is rigidly connected to the yoke 78, leaving no lubricated joint within the piston. The piston fits loosely in parts

75 and 78, and tight in part 74. Besides having the water-jacket on this part it may be further protected from heat and dust by a groove, feeding air down to the combustion chamber; to do this air is provided by a small pump on the piston at 89. A flexible pipe provides water to cool the piston interior.

27. After being heated and expanded the gases are discharged through the self-cleaning valve, 110. This valve is hollow and water-cooled, as is also its casing, 116. Compressed air seats the valve, and mechanism raises it. Injury from sparks, etc., is

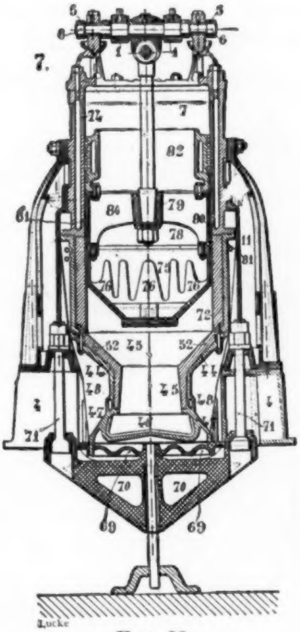

Fig. 93.

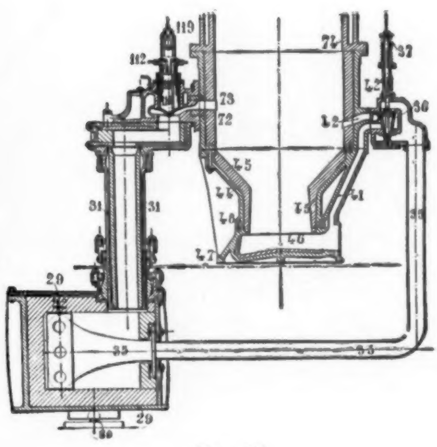

Fig. 94.

prevented by drawing the valve up in its sleeve casing. To protect the seat it is made narrow and cleaned by escaping air. Exhaust gases are discharged through the regenerator, or preheater. This machine, though very complicated, presents many suggestions that may be of value.

It will be observed that the combustion of coal calls for a great complexity of parts and functions, and this must be so. We have, as one of the greatest troubles, the impossibility of regulating the heating power with time of a coal fire, and there is the inevitable dust and ash. This makes the use of oil and

gas with the necessarily simplified apparatus almost mandatory in internal-combustion engines, especially those of moderate size. While here we should have none of the coal troubles, we will meet others incidental to the feeding of fuel as it is required, and only for the instant that it is required.

Oil-burning Engines.

28. In 1865 Stephen Wilcox, Jr., proposed an oil-burning engine, shown in Fig. 95. He said, "The extraordinary develop-

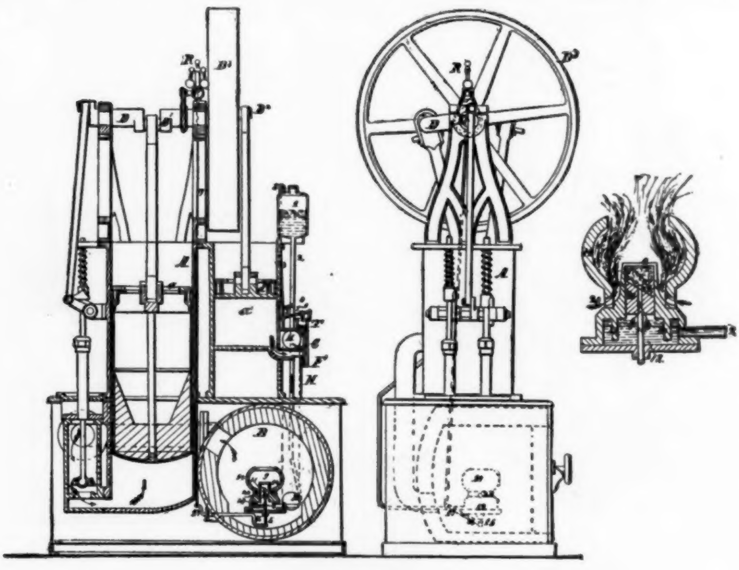

FIG. 95.

ment of what is known as petroleum oil and the several products obtained therefrom, makes it practicable to produce and work very small engines on this plan."

A, the working cylinder, and a^1, the pump, differ in no part from what we have seen in the coal-burning engines. The means for feeding and burning the oil are, however, new and of especial interest. Fuel is fed from an elevated tank, 1, through pipe 2; the interior pressure of the furnace is balanced on the surface of the oil by pipe 3. A stop-cock, 4, is provided, which is arranged to shut off oil by a piston and links, when the furnace pressure exceeds what is desired; this serves to govern

the machine. Oil flows into a vaporizing reservoir, 12 having lugs, 13 to conduct heat from above. The upper part of this reservoir is cylindrical and provided with holes, 10, and fitted with a loose part, 11, with inclined top and a hole in the centre matching the movable pin, 14, actuated by the governor. This pin and hole act to close the vapor outlet. The special construction of the burner is intended to give a constant velocity of efflux to the vapor.

This combustion may be classed as the burning of a jet of vapor in an atmosphere of air, the air about the flame being kept fresh only by convection.

Governing is effected by a double means; the fly-balls act to shut off vapor and increase of pressure cuts off the fuel.

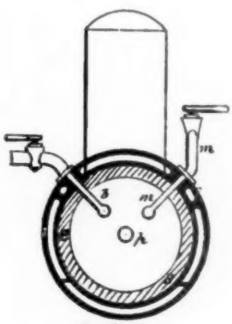

FIG. 96.

29. A. H. De Villeneure in 1872 proposed an engine in which he provided a combustion chamber, having a platinum rose, *p* (Fig. 96), on which impinge jets of oil vapor from *b* and air from *m* provided by pumps. He thus expects to obtain a combustion to heat the mixture.

George B. Brayton in 1872 proposed and built an engine that was very complete and fairly successful. Fig. 97 is a general view and Fig. 98 his oil burner.

Air is compressed in the single-acting pump, which has a volume one-half that of the power cylinder. The compressed air passes from the constant-pressure receiver through pipe *D* and over the absorbent material *e*, through which the fuel is fed by a pump. Here it takes up vapor and the mixture passes the wire-gauge grating and into the cylinder, where it burns.

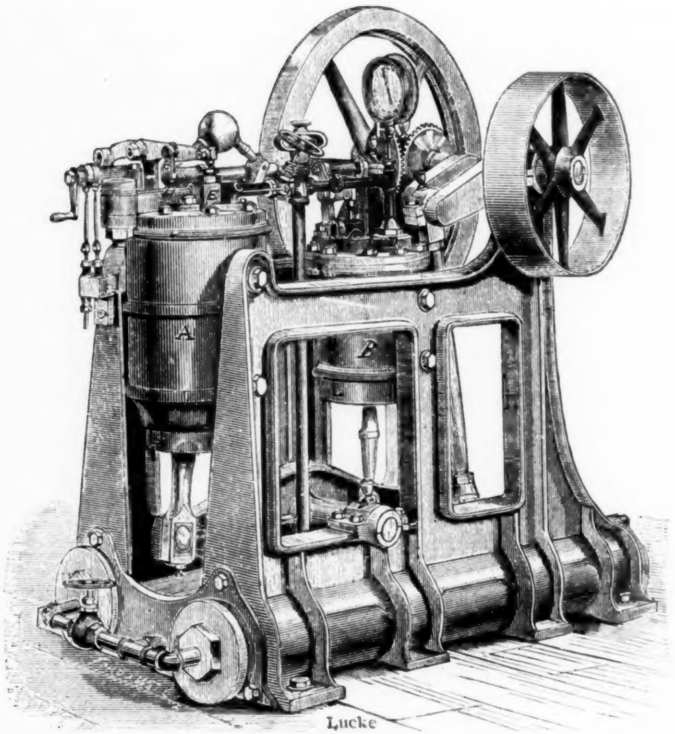

FIG. 97.

Means are provided to prevent entirely shutting off the air from the power cylinder, and thus there is kept constantly burning a small flame which increases for the power stroke. Governing is effected by a variable cut-off to the power cylinder.

The power cylinder is water-jacketed, and no trouble is experienced through overheating. A safety valve is placed on the reservoir.

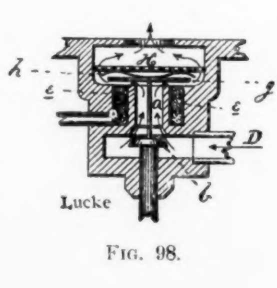

FIG. 98.

30. Joseph Hirsch, in 1874, proposed the engine shown in Fig. 99. An air pump, L, supplies air to a cylinder, H, to take the place of converted air which is periodically expelled; J is a regenerator connecting the two cylinders, A and H; N is a water chamber for cooling gases. Fuel is injected at B^2. When the piston C moves down, air from G is sent over through the regenerator, partly heated here and then further heated by fuel at B^2. On the up-stroke the products of combustion pass over the regenerator to H, being thus doubly cooled, first by the regenerator and second by the injected water. Part of the products of combustion escape at k and are replaced by fresh air. No means for ensuring the combustion of fuel in the atmosphere of air and products of combustion are provided.

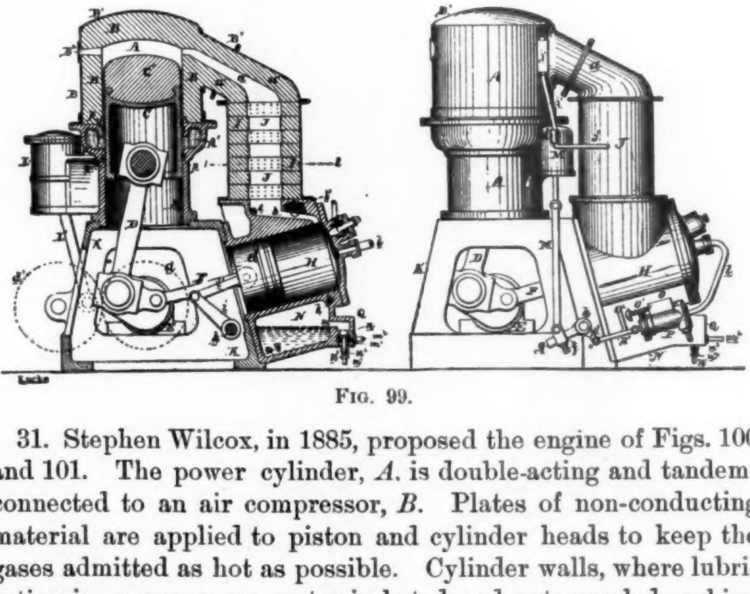

FIG. 99.

31. Stephen Wilcox, in 1885, proposed the engine of Figs. 100 and 101. The power cylinder, A, is double-acting and tandem-connected to an air compressor, B. Plates of non-conducting material are applied to piston and cylinder heads to keep the gases admitted as hot as possible. Cylinder walls, where lubrication is necessary, are water-jacketed, and water-cooled rocking valves of the Corliss type are provided; air is sent to the exhaust preheater C from the pump before passing to the power cylinder, and is, therefore, first warmed and later heated by combustion, in its passage over the gauze grating, S, where it meets the liquid fuel. The valve mechanism permits varying the cut-off and reversing.

A reciprocating tube carrying a lamp works in each port r and serves as an igniter in connection with an exterior relighter.

The receiver is first charged with air by a hand-pump, and a little fuel sent to the burner by hand. Valve 24 in the escape pipe 22 is closed and a torch applied to the burner through *w*. The engine may now be started by opening the main stop-valve, 28, and automatic action begins.

32. Rudolph Diesel, in 1892, proposed the oil-burning motor shown in Fig. 102. A single-acting cylinder *C* carries the plunger

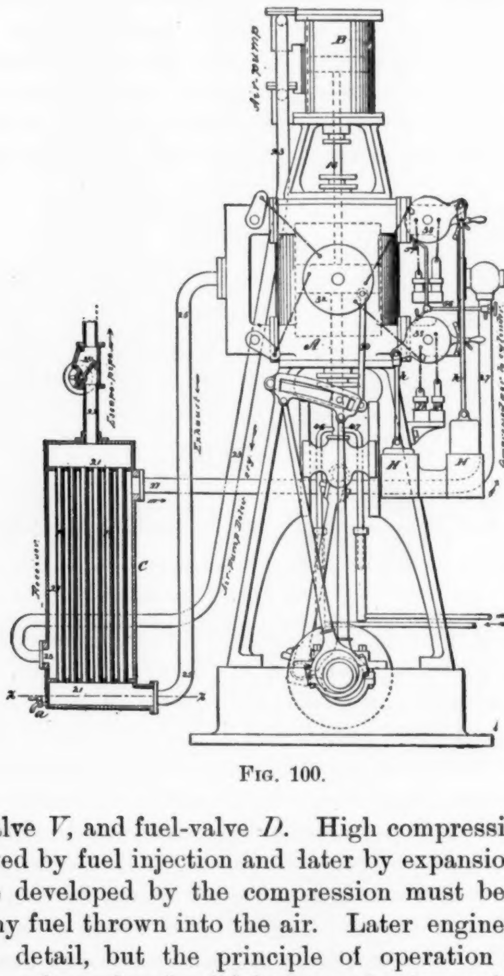

FIG. 100.

P, air-valve *V*, and fuel-valve *D*. High compression of the air is followed by fuel injection and later by expansion. The temperature developed by the compression must be sufficient to ignite any fuel thrown into the air. Later engines vary somewhat in detail, but the principle of operation is the same. Gaseous and powdered solid fuel can also be used.

It is obvious that the quantity of fuel injected per stroke will determine the cycle. If only sufficient is admitted to keep *T*

constant, we have Cycle IV., or some of its variations; if enough heat results to keep p constant during combustion, we have one of the Cycles III.

33. B. V. Nordberg and C. E. Shadall proposed in 1895, not a complete engine, but a system of operating engines by internal combustion; the apparatus is shown in Fig. 103. The products of combustion are to be used in any way deemed advisable.

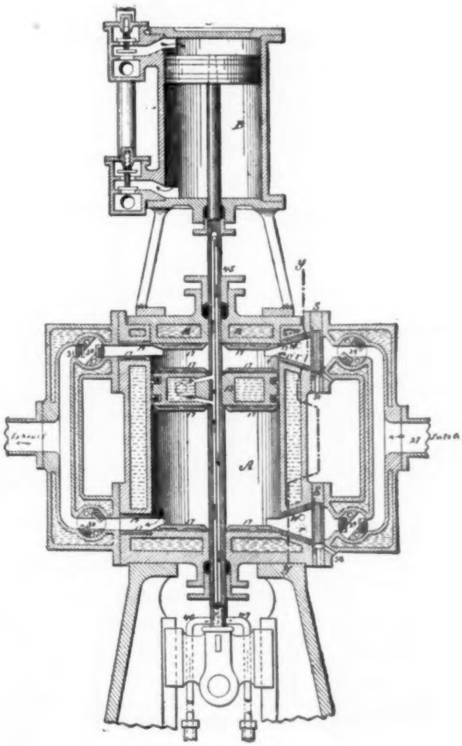

FIG. 101.

A source of air supply and means for using the products are assumed. Oil is fed from a tank B by water displacement, the same water-jacketing the combustion chamber C. This combustion-chamber jacket may add steam to the products at c_1. The air current from the compressor acts (1) on the surface of the water A; (2) at the oil atomizer E; (3) at the lamp I; and (4) with reduced pressure at the opening c in the burner. The

atomizer is fed with oil through the pipe *b*, and the float b^3 prevents, by proper specific gravity, an overflow of water. The oil passes up to the nozzle, where it meets an air current and is there sprayed into the chamber C^1; the spray meeting a flame jet from the lamp at *i* in an atmosphere of air provided through *c*, is enabled to burn. Increased pressure cuts off the oil supply.

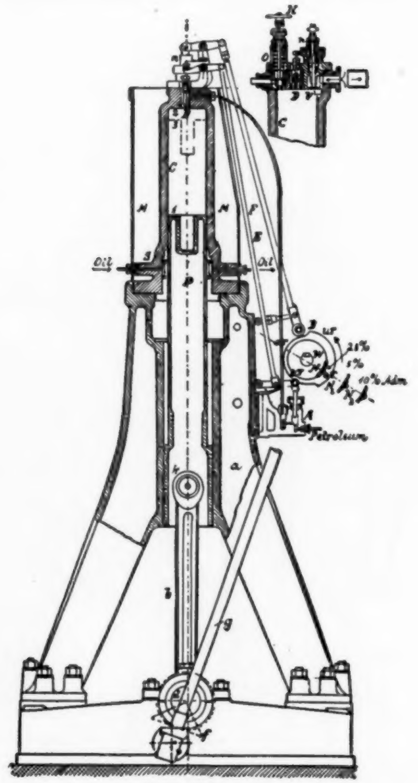

FIG. 102.

Gas-burning Engines.

34. The operation of engines of the class we are considering by a gas combustion offers what would seem to be the simplest solution, but in reality the difficulty is much greater than might be supposed. Of course, no trouble will be experienced with dust, vaporizing of oil, or soot from imperfect oil combustion, but there appears the difficulty of finding a burner which will

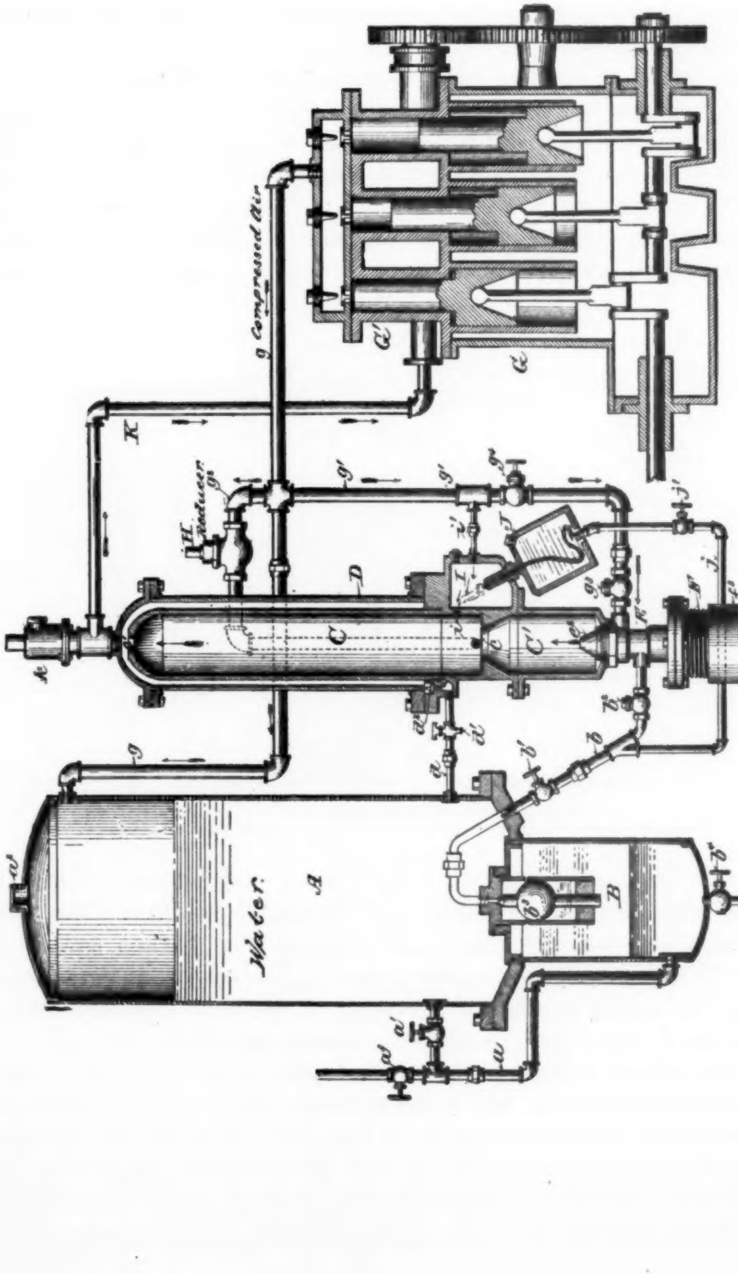

FIG. 103.

completely consume the gas without excess of oxygen under the widest possible range of conditions. The engines proposed differ chiefly in the means proposed for accomplishing this gas combustion.

Stephen Wilcox, in 1865, proposed the machine of Fig. 104. Air and gas are supplied through pipes *K* and *J* from feed-pumps *G* and *H* to burner *j*, and the mixture is ignited at *R*. When the gas is to be supplied by vaporizing oil, the exhaust-heated vaporizer *N* is introduced. *A* is the power cylinder, *B* a changing cylinder, and *F* a regenerator. When *b* descends, the valve *M* allows cold air to fill the top of *B*; this air, on the up-

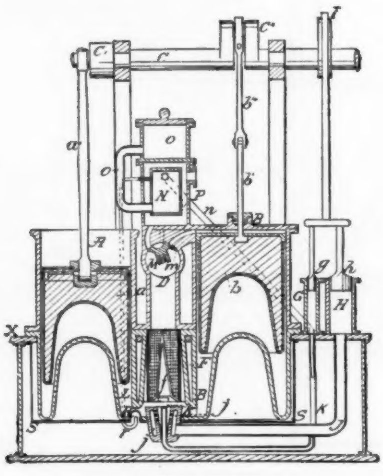

FIG. 104.

stroke, moves through the regenerator and burner, which at this time delivers its mixture; this double heating raises the pressure in the system, and the piston rises. Then both descend and exhaust some gases into *P*. The engine is thus operated not solely through the heating of products of combustion, but by the heating of a mixture of these gases with pure air.

35. Albert Schmid and J. C. Beckfeld proposed, in 1889, the system of obtaining hot gases through internal combustion of air and gas by the apparatus of Fig. 105. Gas and air are supplied by pumps to tanks *A* and *G*; they are mingled in an injector chamber S^2; thence passing through the perforations *t*, they are burned at *S*. To maintain a difference of pressure in

the tanks and combustion chamber a relief valve *O*, controlled by a diaphragm, is provided. To dilute the products of combustion and reduce their temperature, a pipe *L* conducts fresh air to the mixer S^1. Electric ignition is suggested.

Later, another arrangement, shown in Fig. 106, was suggested. Here a long perforated brick *O* is inserted to aid combustion and act as a reigniter. A receiving reservoir is added, to which the blow-off is attached. An igniting plug *V* of coke or carbon is also added.

In Fig. 107 is shown an addition of a steam boiler with an ex-

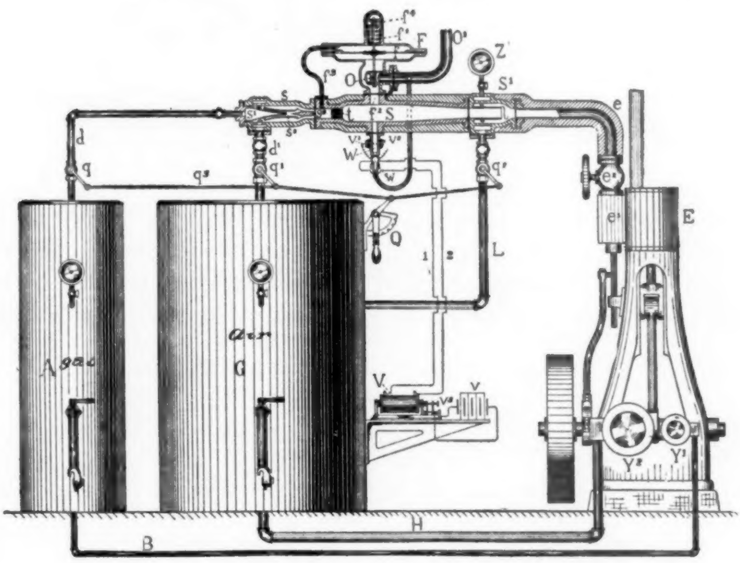

Fig. 105.

haust gas feed-water heater. The boiler is to be used in starting with an ordinary external combustion fire-box, and, later, enclosed, mixing the steam and products of combustion.

36. Herman Schumm, in 1895, suggested the engine of Figs. 108 and 109, which offers some novelty. *A* is the engine cylinder, *B* the piston, *C* an inlet for combustible mixture, *D* an inlet for pure air, and *E* the exhaust valve. An electric igniter, *i*, is provided, and a gauze diaphragm, *g*, prevents back flash. Air is compressed by the pump and stored in *G*, gas similarly compressed by *H*. Air is admitted through *D* until the piston has moved out a short distance and then cut off; at the same time

the air and gas mixture is admitted through C and ignited, the combustion operating on the gauze until the mixture is in turn shut off, when adiabatic expansion begins.

37. Sydney A. Reeve, in 1897, proposed the apparatus of Fig.

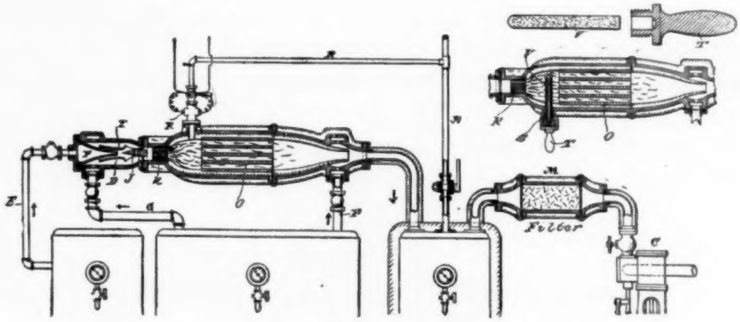

FIG. 106.

110 to obtain by internal combustion working gases to be used in an engine. He lays stress on two points: one, relating to the combustion, that the proportions of fuel to air shall not materially vary; and the other, the reduction of the

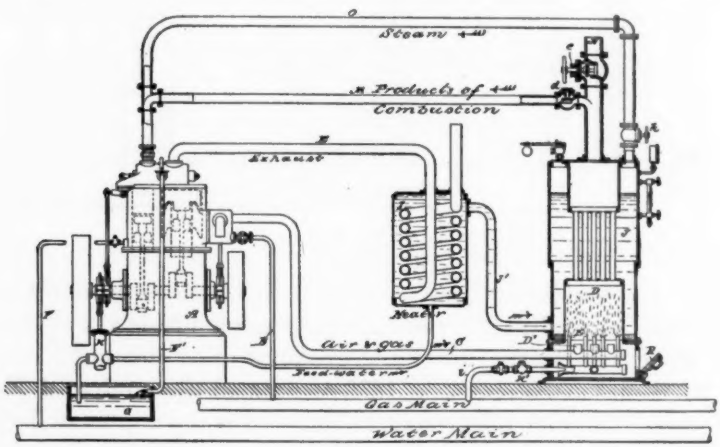

FIG. 107.

temperature before sending the products of combustion to the engine.

Both air and fuel are to be supplied by separate pumps, and the proportions regulated by maintaining the pressures in

the two receivers, C and C^1, equal by water seal and float valve, and by passing these gases of equal pressure through a double-ported valve D of proper areas. The pressure in C is controlled by that in C^1, and that in C kept above that in the combustion chamber by the loaded check G. This also permits mixing fresh air with the products of combustion if more than is wanted for combustion is available.

The products of combustion pass through water so supplied as to keep a given quantity always on hand and at the boiling point

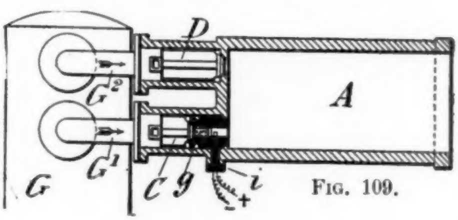

FIG. 109.

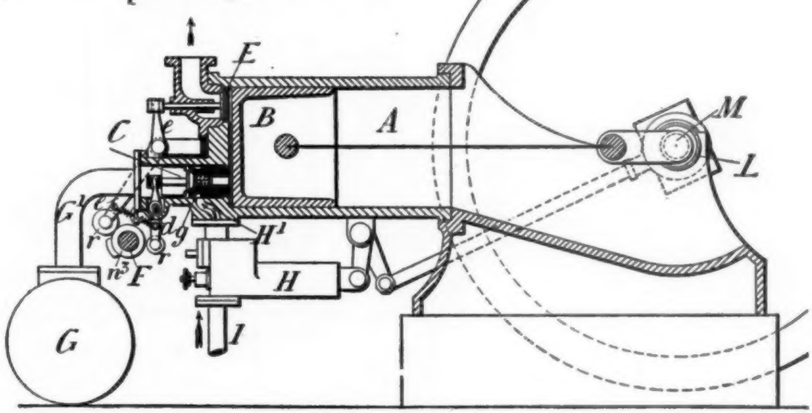

FIG. 108.

corresponding to the pressure, so that the hot gases will, in parting with their heat, evaporate water and be themselves cooled to the temperature of saturated steam at their pressure. Of course, any feed-water supplied must be heated before evaporation, but this only has the effect of decreasing the rate of evaporation without stopping it.

Another device proposed for equalizing pressures in the air and gas receivers is to let fuel pass through a flexible-walled bag suspended in the air tank.

38. The cooler and burner might also be arranged as shown

in Fig. 111. The regulator valve has a spring-balanced diaphragm, 4, which actuates a similar plunger, 6, by rod 5, the plunger moving in a perforated sleeve. Gas enters through tube 12 in the centre and air through 10, the mixture passing an igniter at *b*. A liquid seal is provided here for maintaining a decrease of pressure between supply and discharge valves.

39. Lucius T. Gibbs, in 1897, proposed a system (Fig. 112), in which the motive power shall be air admitted to the power cylinder from a source under pressure, and when the pressure after cut-off has become so far reduced as to reach that of a

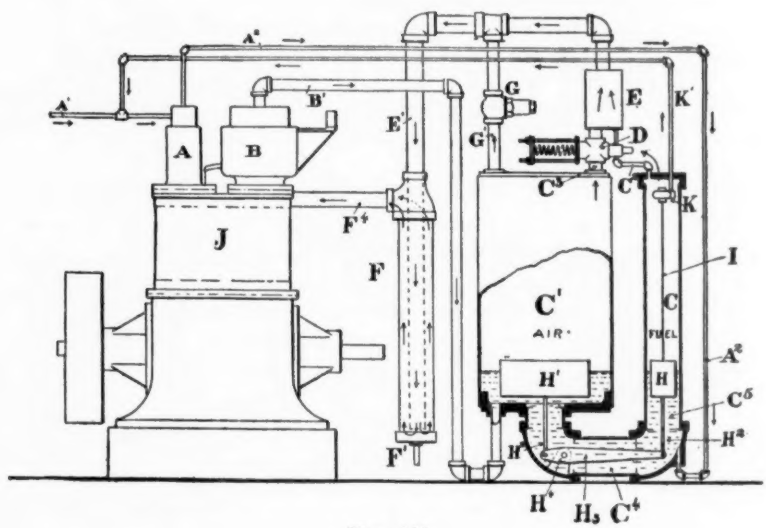

Fig. 110.

stored mass of gas maintained lower than the air supply, the gas will enter and be ignited, thus tending to keep up the pressure during the expansion. Thus the adiabatic will be raised to perhaps an isothermal or higher.

40. If we would trace any line of progress through these machines, we could not make our division according to the fuel used, as at times engines burning all kinds of fuels have been suggested simultaneously. To be sure, before the possibilities of petroleum were known, the principal fuel was coal, and, naturally, in early engines coal fires predominate; though it would seem that they would gladly be dropped for oil and gas, yet they were not, and continue to appear from time to time.

There is a division, however, in the stages of progress that is significant, as showing how strong is the influence of the known and tried on the proposals of apparent novelty. The old so-called hot-air engines of the Ericsson type had a mass of air

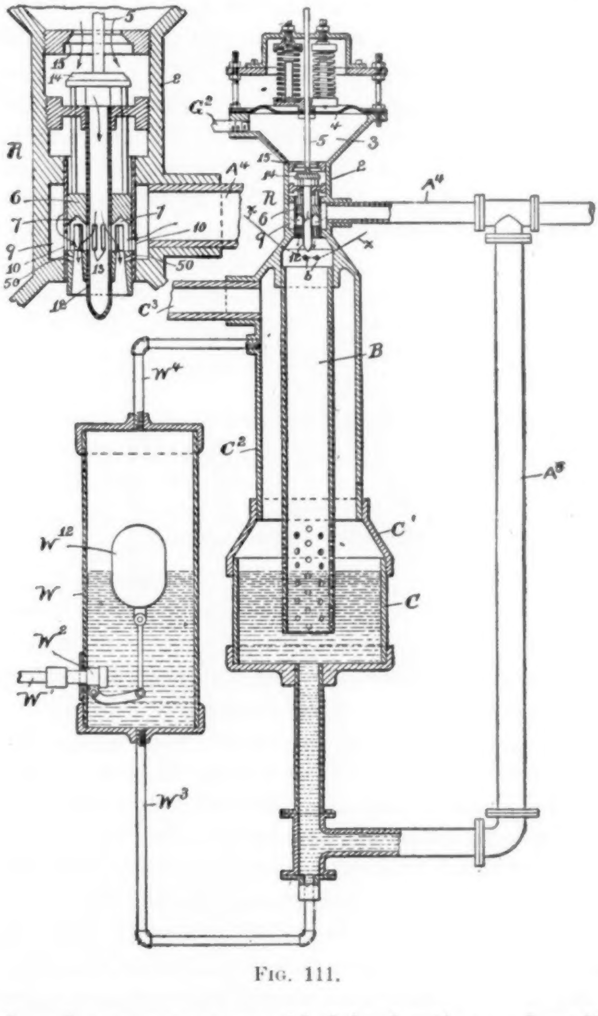

FIG. 111.

enclosed, and means were provided for heating and cooling the same mass without exhausting, the heat, of course, being supplied through walls from an outside fire. So we find the earlier internal-combustion engines working on a system only slightly different from the above. There is a mass of gases enclosed,

and means for transferring them from a hot part to a cold part, and so varying their internal pressure, but the hot part is here provided for not by a hot plate, but by a short flame injection, or passage over a fire. The operation was to depend chiefly on the alternation of hot and cold in the same mass.

41. Later this system was developed by injecting more and more fuel, or by causing the mass to pass entirely through the fire, necessitating more fresh air for the next time and calling for an exhaust; finally we have a regular admission and exhaust, the gases passing continuously in the same direction, and no alternation of heating and cooling being attempted in the system. Any cooling that is to to take place must occur outside

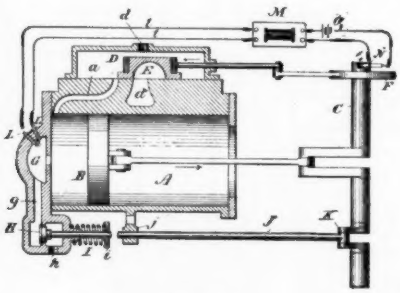

FIG. 112.

the machine in the atmosphere, and the resulting contraction of the gases forms no part of the working cycle.

42. The engines presented represent by no means all of those suggested, but are selected from a very large number to show the principal ideas advanced in the past. By studying them we can reach an understanding of what points may be accepted as solved, and what are still open for discussion and research.

It will be observed that these non-explosive internal-combustion engines may be divided into (I.) intermittent internal combustion, as in Genty's, Brayton's, Wilcox's, Diesel's, etc., in which the air and fuel pass the power-cylinder valves before combustion; and (II.) continuous internal combustion, as suggested by Schmid and Beckfeld, Reeve, and Nordberg and Shadall, in which the hot gases are continuously produced, and afterward utilized by passing through valves to the power cylinder, or by expanding through a turbine without valves.

43. Different ways of doing the same thing by varying details have been advanced, and it may be well to bring these together in some cases for comparison.

Cylinders:

Both single and double acting, jacketed and unjacketed are found. Air and power cylinders may be independent, or the two operations of compression and expansion performed in opposite ends of the same cylinder. When this is done, the cylinder may be of the same diameter throughout, or reduced at one end. Independent cylinders have been connected by beam, separate cranks on the same shaft, and in tandem. In most of the intermittent-combustion type the piston fits a part of the cylinder only, and is loose in the hot end; in this case, heat is prevented from reaching the working faces by prolonging the piston, and by blowing cold air or steam down around the loose part toward the hot end.

44. Igniters:

With engines using oil or gas, where combustion may be entirely interrupted for a time, some form of relighter must be provided. This may be

I. A plate heated by an external jet from outside. Nordberg.

II. A platinum rose, with mixture impinging. Villeneure.

III. High temperature of compression. Diesel.

IV. A plate or wire electrically heated. Wilcox.

V. Introduction of incandescent solid. Schmid and Beckfeld.

VI. Electrodes with spark gap. Babcock.

VII. Introduction of auxiliary flame continuously. Nordberg and Shadall.

VIII. Introduction of auxiliary flame intermittently. Wilcox.

IX. Constant-burning flame in cylinder. Brayton.

45. Use of water:

I. In compression to cool air.

II. To be evaporated by products of combustion by contact and adding steam produced.

III. To cool expanded gases and produce partial vacuum.

IV. To cool hot parts and be discharged.

V. To cool hot parts and add steam.

VI. In an internally fired steam boiler, which may act as a starter.

VII. As a jacket to hot parts, the steam used in a separate cylinder.

VIII. As an annular piston cooler to prevent contact of hot gases with working face of cylinder.

46. Methods of governing:

I. Throttling air intake.

II. Throttling passage between the air and power cylinders.

III. Varying cut-off at power cylinder inlet.

IV. Varying combustion chamber pressure by fuel cut-off.

V. Varying internal pressure, by splitting the air from the compressor and sending more or less of it through or around the fire.

VI. Varying internal pressure by blow-off.

VII. Combination of varying initial pressure to power cylinder, and varying cut-off to same.

VIII. By throttling the exhaust.

47. Preheating and regeneration:

A heating of the air after compression, and before reaching the fire, will insure a good combustion, and if this is done by exhausted heat, it aids the economy of the engine.

I. Causing the air approaching the fire to first surround the fire-box as a jacket.

II. Causing exhaust and compressed air to pass on opposite sides of a plate.

III. Alternately sending fresh air and exhaust through the same chamber, which must then be present in duplicate.

IV. Combination of exhaust regenerator and fresh air fire-box jacket.

48. Fuel feed:

Coal may be fed by any automatic stoker, and from above, below, or the side; we will omit these.

I. Oil by gravity, cut off by internal pressure.

II. Oil by pump, cut off by by-pass.

III. Oil by water displacement, cut off by internal pressure.

IV. Oil by injector suction.

V. Gas by pump.

49. Gas and oil burners:

I. Air and gas fed from opposite openings, jets impinging. Wilcox, Reeve.

II. Air and gas fed through separate openings, the jets mixing by impact with platinum rose. Villeneure.

III. Air and gas mixed, fed through simple opening. Babcock.

IV. Air and gas mixed, fed through gauze screen. Brayton, Schumm.

V. Air and gas mixed by injector at burner, passing through openings into larger chamber, and products through openings similar to first, but larger in area. Schmid and Beckfeld.

VI. Volatile oil vaporized by heat of burner burning in atmosphere of air. Wilcox.

VII. Volatile oil vaporized by falling on hot plate in atmosphere of air. Schmid.

VIII. All kinds of oil sprayed into atmosphere of air. Nordberg and Shadall.

IX. Volatile oil dropped on grating, where it meets air, the mixture burning on one side. Brayton, Wilcox.

X. Hot-air atmosphere for an injection of fuel. Diesel.

50. Mixers and proportioners:

I. Mix at burner, proportions maintained only by pump of proper size.

II. Pass air through volatile oil kept at fixed temperature by exhaust.

III. Mix at burner, proportions maintained by pumps of proper size, aided by a device to feed both pumps at constant pressure.

IV. Proportions maintained by (*a*) movable partition between air and gas receivers, to keep pressures equal, and (*b*) proper double valve at the discharge.

V. Mix at injector, with no special device, for proportioning.

Position of fire:

I. Directly under piston.

II. At side of cylinder; each end, when double acting.

III. In separate, continuously operated, highly heated chamber.

Cycles:

Nearly every cycle of operations can be followed. Engines that take air in one side of the cylinder and send it around to the other side, and those with two pistons moving in different directions, causing a change of position of the air only, will give a constant-volume combustion, and whether the engine follows, Cycle II., II*A*., *B*, or *C* will depend on the amount of expansion permitted. Engines feeding the cylinder with a flame may have a constant-temperature, or constant-pressure combustion, depending on the fuel used; hence III. or IV., with all their varia-

tions, are possible. Those engines that maintain a constant pressure in the combustion chamber will follow III., or some of its variations—which one, will be determined largely by the cut-off. A turbine system would follow III. most nearly.

51. Of the engines considered, and the much larger number not mentioned, not one, except the Diesel, is on the market to-day. This, with some, would be a sufficient argument to condemn the whole system, but a little study will show that the trouble is nearly always in the same place, and a little perseverance is all that is necessary to remedy the defect. Much more difficult problems than this have been solved successfully, but there was first necessary a recognition of the trouble and a good reason for spending time and money to overcome it.

The compressing of air is no new problem, and the using of hot gases is done every day in thousands of horse-power of explosion engines, so that these two parts of the engine may be considered solved, leaving, as the only doubtful essential, the fire, and here is the seat of most of the trouble.

52. The old engines, like Cayley's, using coal, were found to cut with ash, etc.; but, nevertheless, when everything was right, they ran and gave a good account of themselves. In the natural order of things, Brayton appeared with a gas machine. The air and gas were mixed in proper and explosive proportions, at the compression intake, and sent through a wire gauze grating to be burned in the cylinder. Clerk says of it:—"The engine worked well and smoothly; the action of the flame in the cylinder could not be distinguished from that of steam, it was much within control and produced diagrams similar to steam." The flame grating of gauze was the weak part, as an accidental piercing or overheating caused an immediate back flash and stopped the engine. Brayton could not stop this, so he tried a volatile oil with compressed pure air, but his burner was very crude and resulted in a goodly soot deposit. The case seemed hopeless, and doubly so when Otto appeared in the field with his successful engine, so Brayton gave up.

Here, however, was a working engine giving good results, both in economy and regulation, needing only a good burner to keep it going.

53. The immediate success and attractive principle of the simple one-cylinder Otto has held the attention of nearly all from then until to-day. One man there was who, not only did

turn aside, but, having turned, persevered, and he was rewarded by success—that was Diesel. He prepared an elaborate plan to imitate as nearly as possible the Carnot Cycle, with its isothermal combustion in a cylinder—certainly a striking novelty. But he did not follow it, as the low mean effective pressure of all the Cycles IV., which he attempted to follow, necessitated immense machines for the power produced; what he did do was to reproduce the Brayton engine with another burner and igniter. His hot compressed air did what Brayton could not do, but in everything else he was strictly Brayton with his Cycle III. of operations, which he ultimately followed. This is one solution, then, but not necessarily the best, as Diesel needs a very high compression to run, and, while this is the reason for his high efficiency, it makes a heavy machine. A little lower efficiency, with less weight, would be very acceptable, but this would preclude the Diesel burner.

54. A detailed study of the combustion of gas and oil should certainly lead to a still further opening up of this promising, though neglected, field of engineering. Produce a good fire and you must inevitably produce an improved Brayton engine, and this, in view of what has been said, is certainly a very desirable end.

While combustion, as a purely chemical process, has formed the subject of numerous papers and researches, leading to most interesting theoretical results of great value to physical chemists, not so many have resulted in the discovery of a new or useful mode of burning fuels.

55. Investigation long ago showed that the oils undergo a vaporization before combustion, and that the oil flame is really an oil vapor, or gas flame, so that a knowledge of the laws of combustion of gases will give us those of oil combustion, with the exception of the means of previously vaporizing the oil. In fact, the different methods of burning oil now in use vary chiefly in this second respect, the means provided for gasifying the oil. It would, therefore, be well to look at the question of gas combustion first.

Gases burn by combining chemically at high temperature with oxygen, and the study of their combustion may be most readily divided into classes whose characteristics are the ways in which this coming together of the gas and its oxygen are provided for.

56. This leads to the division:

Class I. Gas issuing from an orifice into a supporting atmosphere and where all the oxygen for combustion is derived from that atmosphere.

Class II. Gas mixed with oxygen insufficient in quantity for its combustion or for the formation of an explosive mixture, issuing into a supporting medium from which all necessary additional oxygen is derived.

Class III. Gas mixed with oxygen in quantities insufficient for complete combustion, but sufficient for the formation of an explosive mixture, issuing from an orifice into a supporting atmosphere, from which all necessary additional oxygen is to be derived.

Class IV. Gas mixed with oxygen in just sufficient quantities for combustion, issuing from an orifice into any sort of atmosphere. We shall call a mixture of this sort a "chemical" mixture.

Class V. Gas mixed with oxygen in such quantities as to form an explosive mixture, but with insufficient oxygen for complete combustion, burned in a mass by a single explosion.

Class VI. Gas mixed with oxygen in chemical proportions, burned by a single explosion in mass.

57. The first class of combustion is very imperfect, consequently only low temperatures result, while large excesses of oxygen over what is chemically necessary are required. It is to this very imperfection that we owe the efficiency of our ordinary gas jet as a source of light. The unequal distances travelled by molecules of gas before reaching the place where they can find and combine with the necessary oxygen, gives the flame a volume; *i.e.*, a certain portion of space is filled with the flame. In the study of combustion, as the origin of heat, this class is of no importance. Mixing the oxygen with the gas, previously to heating for ignition, as in Class II., is a direct aid to nature, eliminating the hunting process of Class I., or, at any rate, reducing it, and making necessary only the heating to the ignition temperature to cause combustion. This is shown in the immediate shortening of the flame over that of the previous class, and its loss of luminosity, while still retaining the volume character of the flame. It is the principle of the Bunsen burner, and the large class that follow it for use in furnaces, heaters, cooking stoves, and heating water in steam carriages.

58. In most of these the mixture of air with the fuel is made

by causing the jet of gas to impinge on a mass of air, some of which is carried along with the air under the double influence of gas friction and the heated top of the burner, whence the mixture issues.

Some other systems, of which the American Gas Furnace System is one, effect the mixture in closed chambers before exit at the burner.

Combustion of Class II. is characterized by the fact that there is an actual volume of flame; the flame is hotter than in Class I., which means that for a given flame volume, either more gas is burned, or the products of combustion are less diluted; the flame is less luminous and not of uniform color throughout its volume.

An infinite variety of details of arrangement in the exit and mixing of the air and gas may be devised with varying results for special cases, but we may say of all of them that though the combustion be very perfect and the amount of heat generated large, yet there is always a "flame volume," indicating a struggle, as it were, on the part of the gas and air in their final combustion. The combustion, though approaching perfection in many cases, is rendered so only by the use of a large excess of the oxygen chemically required giving oxidizing products of combustion.

59. It is only when we previously mix the gas and air completely and uniformly in the proper chemical proportions that we can get non-reducing, non-oxidizing products of combustion, and, since none of the heat goes to warm excesses of oxygen or of fuel, the temperature of these products must be the highest possible. Combustion of this sort is flameless, or, rather, what flame there is is without volume, having only length and breadth without thickness, and is, in fact, a surface.

Such combustion is governed by laws quite different from those under which the classes already noted operate, and it is to the combustion of chemical, and other explosive mixtures, that this section is mainly devoted.

60. Let us consider first the class mentioned as Class VI., in which a mass of chemical mixture—*i.e.*, gas and its needed oxygen—is confined in a chamber. If inflammation be provoked at any point of the mass, it will, by self-propagation, finally and successively inflame the whole mass. This is the first and fundamental principle of this sort of combustion. The investi-

gation of this propagation of inflammation by such men as Davy, Bunsen, Mallard and LeChatelier, Berthelot and others, has shown that:

(*a*) In any mixture, the rate of propagation is constant for a given temperature before inflammation.

(*b*) The rate of propagation for such mixtures varies with different combustibles, being, for example, very fast for hydrogen and slow for marsh gas.

(*c*) The rate of propagation increases with the temperature of the mixture before inflammation.

(*d*) The combustion is visible by reason of a flame-cap, or deep blue film of flame, which travels through the mass, and which, at any instant, completely separates all the burned from the unburned mixture.

This uniformity of velocity of inflammation would indicate that in a mass where inflammation had started at a point, the flame-cap, or surface of combustion, exists at any instant on the surface of a sphere whose radius is proportional to the time elapsed.

61. All this has been assumed to take place in a large mass of gas. If, however, the enclosing vessel be given special forms, certain other characteristics are brought out. One which is of interest to us is the fact that, when the enclosing vessel is a cylinder, or prism, in which the combustion surface travels with its centre on the axis, the velocity becomes affected by reduction of cross-section and that there will always exist for every such mixture an area of cross-section so small that the self-propagation ceases. This has been explained by saying that the walls carried off heat so fast that the small flame-cap could not generate heat enough to keep itself above the temperature of ignition. Davy secured the same effect by using his screen of wire gauze, which, if interposed in the path of the combustion surface, instantly cooled the same sufficiently to prevent the ignition of the mixture on the other side, provided, of course, the temperature of the gauze itself is sufficiently low.

62. When a neutral diluent gas, such as N or CO_2, is added to a chemical mixture arranged for the above-discussed combustion, its effect is to reduce the rate of propagation, though not in conformity with any law yet discovered. Of course, there will be a point when so much of the neutral gas is present that combustion is impossible, but no reliable data are at hand

on this point, as the same conditions often give widely varying results.

While large quantities of a neutral gas may be added, without affecting the combustion except to decrease the rate of propagation, a dilution by a comparatively slight amount of oxygen will prevent it altogether. An excess of gas, it has been found, will act within certain limits like the presence of a neutral gas. By far larger amounts of fuel than of oxygen may be present in excess without arresting combustion.

63. This brings us to class V., where explosive mixtures are burned in mass, the mixtures having excess of fuel. The combustion is possible within quite wide limits, with no other effect than varying the rate of propagation. In fact, we see a great deal of it to-day in our gas engines. While, of course, we should, in these engines, invariably use the proper chemical mixture, they are seldom, if ever, constructed to maintain this properly, and, as a slight excess of oxygen will completely prevent inflammation, the error is always made on the other side; sooty exhausts bear testimony to this. The gas engine also gives evidence of the fact that neutral gases decrease the rate of propagation, for in some two-cycle engines which I have lately examined I find it impossible to get a vertical combustion line on the indicator diagram with a fixed ignition, except at very slow speeds—about 50 revolutions per minute. This is due entirely to the presence of exhaust gases in excessive quantities as diluents to the charge.

Some of the principles above noted as belonging to masses of mixture at rest will make clearer the nature of the problem of combustion of the same mixtures when in motion issuing from an orifice.

64. The desirability of being able to burn an explosive mixture continuously and non-explosively under commercial, rather than laboratory, conditions having long been obvious, a series of experiments was undertaken at Columbia University with this end in view. Many experiments were made and various results obtained, but as a full account would take too much space and avail little, only a few characteristic experiments will be noted as leading up to the result. Consider a mass of explosive mixture passing through a non-conducting tube with a uniform velocity v. Then, if inflammation be started at some point, the surface of combustion may remain at rest or move with or against the current. Denote the rate of propagation by r. Then, when

$v > r$ the surface of combustion will move with the current, and if the tube has an end, the flame will "blow off" and combustion cease; if $v = r$ the surface of combustion will remain at rest, other influences being inoperative; if $v < r$, the surface of combustion will move back toward the source or "back flash."

Of course, a small tube of heat-conducting material will exert considerable cooling effect, but for the present we will not consider such tubes.

In a practicable system of burning an explosive mixture continuously, we may state the following as desiderata and later see how they can be secured.

I. "Back flashing" must be prevented.

II. "Blow off" must be prevented.

III. Combustion surface must be localized.

IV. It must remain localized for wide ranges of feed or velocity of flow of the mixture.

V. The localization must be unaffected by changes of temperature.

VI. Large or small quantities must be burned without affecting the above, and the transition from very small quantities to very large, or *vice versa,* however sudden, should be easy.

65. The first requirement might be accomplished in three ways:

(*a*) By using a long tube of some conducting material and so small in diameter as to prevent the passage of the flame-cap under any circumstances.

(*b*) By using wire-gauze screens.

(*c*) By causing the mixture to flow at some point with a velocity always greater than the rate of propagation.

The first (*a*) is impracticable, as it permits of only small quantities being burned; the second (*b*) will not work when the wire gauze gets hot; this leaves (*c*), which is practicable, as a valve in a pipe will answer for the necessary contraction and consequent increase of velocity. Hence we must put down as the first requirement in our desired method of combustion the following. At some point before the combustion surface is reached the velocity of feed must be such that $v > r$.

66. Requirement II. might be accomplished in three ways:

(*a*) By so reducing the velocity after passing the high-speed point that we have at some surface $v = r$.

(*b*) By suddenly increasing the temperature of the mixture so

as to increase the rate of propagation while v remains constant; or,

(c) By both reducing v, by spreading the current, and increasing r by heating.

All of these ways are practicable; but, as a reduction of velocity alone, or a sufficient heating alone would not produce the desired results so well as both operating together, there was introduced as the second requirement in our desired method, the following. After passing the point where $v > r$, the velocity of the mixture should be so reduced and its temperature increased as to make $v^1 = r^1$.

67. With these conditions in mind, let us consider an experiment. Let the mixture issue from an orifice into the air. By properly regulating the velocity of exit, the flame-cap can be maintained at the orifice—the only device with which I succeeded in this experiment was by causing water to drip into the supply chamber; the position of the flame-cap is so extremely sensitive to changes of flow that all other methods which were tried for obtaining a constant velocity of exit, variable at will, failed—increase the flow slightly, and the flame-cap will lift off. This may be done until the flame-cap is as much as 2 inches (with illuminating gas and air) from the orifice before extinction takes place. It would seem that the impinging of the jet on the atmosphere should spread it and so reduce its velocity, but no appreciable increase of diameter could be observed. When the cap is close to the orifice, it is of a deep blue color, uniform in shade over the disk, and the edges are sharply defined; whereas, as it lifts off some distance, it becomes indistinct and unsteady at the edges until, at the moment of extinction, it fades into nothing. When the cap is away from the orifice, while there is no visible connection with the source of supply, there really exists a column of mixture extending from the orifice to the cap and passing through the atmosphere. Naturally, at the surface of this column, diffusion will take place, and the longer the column, the greater will be this diffusion effect, thus affecting the composition of the advancing column of mixture and causing partial loss of gas. This is the real cause of extinction.

68. From these experiments we can draw the conclusion that the current cannot be sufficiently reduced in velocity by issuing into an atmosphere of lower pressure to. prevent "blow-off" before diffusion with the atmosphere so alters the character of

the mixture as to cause extinction before reaching the surface of combustion. This calls for a new condition besides those noted in the requirements for combustion. The reduction of velocity of the mixture, after passing the place where $v > r$, must be accomplished in such a way as to prevent diffusion with any other gas.

69. To prevent this diffusion, there naturally suggests itself the expedient of surrounding the issuing jet with a shield of larger diameter, to still permit of the desired expansion. This is shown in Fig. 113, and is essentially the same as proposed by Ladd, Schmid, Beckfeld, and others. The mixture must issue from orifice a with a velocity $v_a > r$; this will prevent "back flash." If the distance from a to b is long enough to allow the gas to spread and reduce velocity, "blow-off" will not occur until $v_b > r$, and within these limits the flame-cap should re-

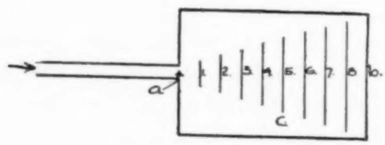

FIG. 113.

main within the shield. A trial shows that when $(Dia)_b$ is but slightly larger than $(Dia)_a$, the feed velocity may be varied in about the proportions noted, but this means that we are confined within very narrow working limits. The flame-cap seems to lose its flat, volumeless character for some reason not at first clear. When $(Dia)_b$ is much larger, say four or five times $(Dia)_a$, a slow increase of feed velocity above r reveals the advancing flame-cap just as if the shield were not there. Later, a slight spreading is noted, and then the flame actually begins to show volume, as if there were no longer an explosive mixture present; this heats up the shield. A little consideration will show this to be due to the diffusion of the advancing and slightly spreading column with the products of combustion within the shield, and the high temperature of the shield helps to maintain a combustion of what is now a diluted explosive mixture beyond a point where that combustion would be possible if cold. An increase of velocity will cause extinction by "blow-off."

70. Here the results are somewhat better than in the last case without the shield. The principles operating, with the results are: back flash prevented by sufficiently great initial velocity at *a*; a spreading to reduce velocity, but very slight and insufficient, as proved by the narrow working limits; diffusion is not prevented; gas is partly heated before burning by the shield, which helps to continue combustion. If the advancing column did increase in cross-section and decrease in velocity while advancing, successive possible positions of the flame-cap would be as shown at 1, 2, 3, 4, etc., of Fig. 113.

It is obvious that at any point between *a* and 7, such as 4, the cap is surrounded by products of combustion, and the advancing column of mixture is passing through an atmosphere chiefly composed of the same, resulting in disastrous diffusion.

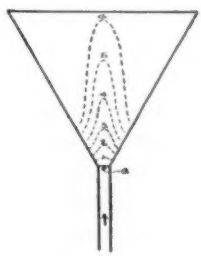

FIG. 114.

This at once suggests giving the shielding envelope the form of a cone, supposing the orifice circular, so that the flame-cap at any instant may entirely fill up the space between the walls.

71. Apparatus with this end in view was tried and gave some interesting results. Fig. 114 shows a cone of 45 degrees angle, with a $\frac{1}{8}$-inch orifice such as was used. The velocity of feed was so adjusted as to cause the flame-cap to advance slowly from *a*, with the expectation stated above. The flame-caps at successive positions took the forms shown at the lines 1, 2, 3, 4, 5, 6, etc., and finally "blow-off" occurred. Since the only place where the combustion surface can remain at rest is on a surface where $v = r$, and since, secondly, r is here constant, the curves indicating the intersection of the combustion surfaces by meridian planes, give us graphical values of the velocity of the advancing column of mixture. It is seen that the expected spreading did not take place, and that at any circular cross-section of the

cone, the velocity was greatest at the centre, decreasing toward the edges.

The curves 1, 2, 3, etc., are really cross-sections of successive constant-velocity surfaces in the advancing column, and the surface of combustion will lie on that surface of constant-transmission velocity where $v = r$.

72. A constant-velocity surface may be defined as a surface at every point of which the moving particles of gas have equal instantaneous velocities. If these successive surfaces had remained flat or nearly so, the proper sort of spreading of current and uniform decrease of velocity would be indicated. This gives us an accurate definition of how we want our velocity reduced after passing the point where $v > r$. The velocity of the advancing mixture must be reduced without diffusion, so as to keep the surfaces of constant velocity of such form that adjacent points on any one will be at approximately the same distance from the point where spreading begins. Reducing the angle of the cone, while helping matters considerably, reduces the range of feed velocities within impracticable limits.

73. Many ways of bringing about the above were tried, but only one seemed preëminently good both by reason of its simplicity and effectiveness, for it fulfils almost perfectly the requirements proposed for our desired method; this is, to fill the cone with fragments of refractory material such as pottery, broken crucibles, bits of magnesite, or any other rock that will stand the high temperature without fusing. In cones of 60 degrees, and with a $\frac{1}{4}$-inch orifice, I have found pieces about $\frac{3}{8}$-inch diameter to answer well.

These separate pieces of solid matter interpose many reflecting surfaces without materially hindering the advance of the mixture, and cause it to spread in the way desired, keeping the surface of combustion spherical and preventing diffusion. A variation of velocity causes the spherical surface of combustion to vary only in diameter, and the limits of feed are determined only by the size of the cone.

74. A cone of given altitude will give the greatest range of variation of diameter of cross-section when its angle is 180 degrees. This is a plane surface which, with the orifice and broken rock, should appear as in Fig. 115. Here the surface of combustion is approximately a semi-sphere. Trial shows that this arrangement works perfectly, and the limits of feed are deter-

mined only by the size of the pile of rock surrounding the opening. A cone of 360 degrees, or no cone at all, suggests the surrounding of the nozzle by broken rock without any enclosing walls (Fig. 116). This arrangement also works remarkably well.

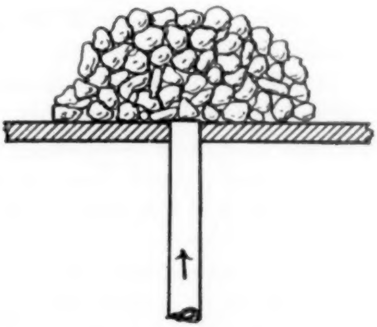

FIG. 115.

The surface of combustion is here approximately a sphere, giving the greatest possible increase in area of the surface of combustion for the distance travelled from the nozzle.

If d denote the distance from the point where spreading begins to the surface of combustion and S the area of the surface, we have:

For a cone, $S = \pi d^2 \tan^2 \alpha$.
For no walls (Fig. 116), $S^1 = 4\pi d^2$.

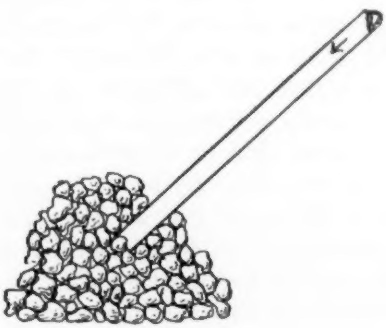

FIG. 116.

75. Not only is the greatest possible range of action by velocity reduction thus obtained, enabling the greatest possible amount of mixture to be burned in a given volume, but this

amount is further augmented by reason of the increase of the rate of propagation caused by the passage of the mixture between the hot fragments. Hence both principles operate simultaneously toward the desired end.

We have thus arrived at a method of continuously burning explosive mixtures of all sorts, whether in the chemical proportion or not, as classified in IV. and V.

76. The method fulfils all the conditions set down as necessary, and may be stated as follows:

I. Cause the mixture to pass a point where its velocity of transmission shall be always greater than the rate of propagation of inflammation through the mixture. This may be done by a valve in the feed-pipe.

II. So spread the current of mixture after it passes this point of high velocity that surfaces of constant-transmission velocity shall be of such form as to keep adjacent points on any one at approximately the same distance from the point where spreading begins. The whole spreading must take place so that the advancing unburned mixture cannot diffuse with any other gas. This can be accomplished by surrounding the orifice with solid fragments, introducing numerous reflecting surfaces which accomplish the spreading; also, by the passage through the interstices between this solid matter, the mixture is heated and the rate of propagation increased, making possible the burning of more mixture in unit volume.

77. When a chemical proportion is maintained in the mixture, all the combustion takes place on the *combustion surface*, giving absolutely neutral products of combustion; but when an excess of gas is present within certain limits, all gas that can find oxygen burns explosively between the solids, while the excess acts merely as a neutral diluent to be burned when it meets an oxygen atmosphere later on. By properly placing the oxygen atmosphere to burn the excess gas, we can get the hot products either *reducing* or *oxidizing*—reducing after leaving the explosive-combustion surface and before meeting the excess of oxygen in the atmosphere, oxidizing after that meeting.

It might be here noted that the principle well known in explosive combustion at constant volume, and constantly operating in the gas engine, that "to a chemical mixture of air and gas there may be added large quantities of gas without altering the explosive properties of the mixture," is, by these experi-

ments, extended. It appears that in explosive combustion at constant pressure, or, as I have called it, "continuous combustion of explosive mixtures," the same principle applies, and, though no real proportion measurements have yet been made, it seems to a wider degree. That is to say, that in the method here described, mixtures of air and gas, with gas in excess of the amount the air present can support, will burn explosively. The excess gas present acts merely as a neutral diluent, such as the nitrogen of the air. It is a fact also that, as the solid fragments heat up, the excess may be greater than when they are cold.

78. Another interesting thing noted in these experiments is that an explosive fire will sometimes emit a musical note; it may be that this is always true and that its absence at any time is due to lack of the proper resonator. This would seem to indicate that what to the eye appears as continuous combustion, is only approaching the limit, which is continuity, and that in reality single explosions in rapid and *regular* succession are taking place. It would be interesting to determine whether the temperature or kind of gas has any influence on this note.

79. The perfection of the gas combustion above discussed and the simplicity of the apparatus make the method highly satisfactory, and the solution of the difficult problem of explosive-gas combustion lends encouragement to the even more difficult case of oil combustion. The experiments with oil, though not yet complete, promise to give equally satisfactory results; in fact, it is almost certain that they will. However, the oil system has so far been tried in only a few cases, and it is not wise to announce the complete success of the system until all possible conditions have been met.

80. It was shown that there were only two classes of combustion worthy of consideration for use in internal-combustion engines, and only two cycles that promised returns commensurate with the labor and time that might be expended in their development—the Otto and the Brayton. The Otto is simple to carry out in practice, and is now, to all intents and purposes, fully developed, while the Brayton has hitherto failed, chiefly because of the difficulty of handling explosive mixtures in the desired way. This difficulty now removed, puts the Brayton cycle on a different basis, making the system quite as feasible as the Otto, and, in most respects, promising better results. Not

only this, but the fact that the oil combustion will almost certainly be put within as easy reach, adds another point in favor of the Brayton cycle, in the carrying out of which any sort of oil may be used, whereas the Otto is here barred.

It is not necessary to enumerate here the comparative merits of the two systems, for that can be easily judged by what has already been stated.

81. There is one point, however, that should receive notice, that is, should we operate Brayton cycles with intermittent or continuous combustion? With intermittent combustion the fire burns within the cylinder, and as nothing but fuel and air pass the inlet valves, they can be the more easily kept cool; while, on the other hand, the placing of the burner beyond the valve presents two undesirable features: first, the clearance must be unusually large; and second, the intermittent feed and cut-off of air and fuel at just the right time, without alteration of proportion in a fraction of a second, introduces a condition very difficult to meet. Continuous combustion within a fire-box is easier to handle, there being no alterations of feed and the clearance may be as small as we please, whereas we have as undesirable the feeding of hot gases past the inlet valves.

Which of these alternatives will prove the better for use, in the system of engines under treatment, can be decided only by actual construction, but as either will work, there is no great risk involved in building.

DISCUSSION.

Mr. Arthur J. Frith.—The careful reading of the paper of Mr. Charles E. Lucke justifies the belief that the interesting part is at the end. His series of experiments on combustion and the conclusions described are of the greatest interest; to many of us they are decidedly novel, and promise to be of great practical value. He is to be congratulated upon presenting us with a most interesting and convincing demonstration of some of the necessary conditions for the complete combustion of gas delivered in a certain stated manner: and we shall be pleased to learn what further problems are solved with regard to the combustion of oil; but this admirable demonstration is only one factor in the heat-engine problem.

His description of various cycles is, I believe, open to criticism;

certainly cycle three is not what I have understood to be the Brayton cycle. One of the noticeable features of the Brayton engine, as we read, was his method of ignition, and an equally marked and apparently necessary feature was that the air and gas were compressed in separate cylinders, and delivered from tanks or directly to the working cylinder. This means that his true card would show a delivery line at highest pressure, reaching toward the origin of ordinates, and the return line of high pressure in the working cylinder is practically superimposed on it, as shown in Fig. 117, so that the true Brayton cycle diagram would be *ABCDEA*, not *BCDEB*. This is a most important difference, for while the mean effective pressure of card *BCDEB* may be large, that of the true card, *ABCDEBA* is comparatively small. All this is admirably demonstrated in Rankine's

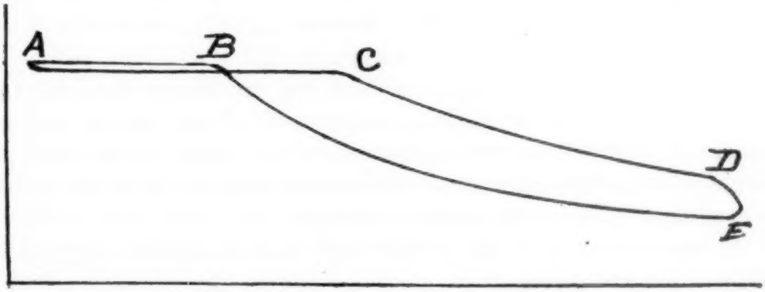

FIG. 117.

"Steam Engine," page 354, in his discussion of the Ericsson air engine, which is a close relative of the Brayton engine, the difference being in the method of heating the working medium. I have worked on a good many schemes calling for cards of this general character, and I have been forced to the conclusion that engines of the Brayton type cannot give high mean effective pressures; in short, that no matter how admirable may be their methods of ignition, and their readiness to work at all times (accounts of which we read in text-books), with low mean effective pressures they must be bulky for the power obtained. Another unfortunate feature which is dwelt upon is that the temperature of the exhaust was excessive, which might be expected from their necessarily small ratio of expansion, where but a slight drop in temperature is obtained from the high temperature of combustion by the adiabatic expansion. I have been told by a gentleman

who saw one of these engines that the exhaust pipe ran red hot, and that the exhaust valve was frequently renewed after being burned out. An English company, it is said, used the exhaust under an auxiliary steam boiler in an attempt to save this loss of heat. Why should we expect anything but low efficiencies in this class of engine, if we cannot use the heat in the engine itself? The recorded efficiencies of Brayton engines were all very low. The use of a regenerator, with its enormous clearance, has been suggested as a means to remedy this trouble but from the well-known conditions of this device, it is believed that this simply adds new and troublesome difficulties to the problem. The experiments and efforts of Professor Jenkin, in England, to use internal combustion with the old Sterling cycle (probably the most beautiful application of thermodynamics that was ever made) are interesting reading in this connection, though the results were entirely unsatisfactory. I have, therefore, doubts as to the reliability of the table preceding paragraph 11.

It has always been supposed that the popularity of the Otto cycle was as much due to the compression of the charge in the working cylinder, by which the tail on the true engine card is avoided, and high mean effective pressures obtained thereby, as to the method of using an explosive charge.

It also seems as if the author were not justified in using the term "Brayton cycle" to cover so many classes of engines, which are in no way related to what Brayton did, or proposed to do: thus in paragraph 53 he says that Diesel reproduced "the Brayton engine with another burner and igniter"—a statement which is so evidently incorrect as to hardly merit a denial, there being nothing in common between the two, unless the slow admission of fuel be so considered, and that has radical differences sufficient to satisfy most people. Carnot, in his cycle, contemplated a slow addition of heat, but I have yet to hear that it was identical with the Brayton cycle.

I firmly believe that we shall yet see an easily controlled internal combustion engine of high efficiency. Mr. Lucke's method of combustion is interesting reading, but I fear it does not solve the heat-engine problem, nor is the well-known thermodynamic inefficiency of the Brayton cycle entirely counterbalanced by its reputed ease of handling.

Mr. H. H. Suplee.—I had the privilege of seeing one of the early Brayton engines exhibited at the Franklin Institute in

Philadelphia, and described by Mr. Brayton. Mr. Frith's figures are about right; the pressure was about 80 pounds, and the exhaust pipe was certainly very hot. Mr. Brayton performed at that time some experiments very similar to those described in this paper: a sphere of sheet metal, some 6 to 8 inches in diameter, which he could take apart, was filled with some resisting material, at one time wire gauze, at another divided material of various sorts, and at another a kind of sponge; in one end of that sphere he delivered compressed air from the air chamber of his engine.

The air chambers of the engine were two horizontal cylinders, which formed the base, as illustrated in Fig. 97 of the paper, and in them he pumped the pressure up to 80 or 90 pounds. At first he had some trouble in holding the pressure over night, so as to have enough to start in the morning, but finally succeeded with air chambers 4 or 5 feet long and about 6 inches in diameter. I think he used ordinary benzine, and by delivering the compressed air into one end of this vessel he burned the carburetted mixture quietly at the other end in a free flame, very much as described here in the apparatus with the broken rock; then, by manipulating the stopcock on the pipe, the flame was blown off in great volume three or four feet away, like a great sphere. The experiments were performed in Philadelphia about Centennial time, and I think that Mr. Brayton has been through most of the work described in this paper before; as we all know, his engine has been in the scrap heap for a long time.

Mr. Lucke.—As to the diagram of Mr. Frith's Fig. 117 being the Brayton cycle, and the one to which I referred not being the Brayton cycle, I would like to say that his diagram would come down to what I call the Brayton cycle if the cut-off had been a little earlier.

With constant-pressure combustion following adiabatic compression we may make this constant-pressure line any length we please up to a maximum by simply varying the cut-off. This variable constant-pressure line will be followed by adiabatic expansion to as large a volume as the cylinder permits, bringing the diagrams all under III., or some of its variations—III*A*., etc.; and, as these are all possibilities resulting from a varying cut-off, I choose to call the simplest and perfect one, III., the Brayton. In this I am merely following custom in these matters. The exploding engine diagram as obtained by operators is always given a slight inclination to the right in the combustion line, as this gives

the best work areas and smoothest operation; constant volume combustion is never absolutely followed by the well informed. This diagram and the perfect one are both called the Otto, yet in discussion we always look to the perfect one, II*A*. This departure from the perfect and simplest card in the Otto engine for reasons of weight, without changing the name of the perfect card from the Otto, is a parallel case with Brayton's practice of having an admission line so long as to make a complete expansion impossible, yet I believe the name Brayton should be given the perfect cycle III. The engine constructed by Brayton did give a low efficiency, as everyone knows; but that does not condemn the cycle, for it is mathematically shown in the papers referred to in paragraph 10 that when the same heat is supplied to the same mass of gas after the same compression, then cycle III., called the Brayton, must give the same work area as cycle II*A*., called the Otto. So that if Brayton's mechanism produced poorer results than this, it is simply an impeachment of that mechanism, and nothing more.

As to the Diesel not being an Otto cycle, I have this to say: Mr. Diesel started out to get isothermal combustion. He found that he was getting too low a mean effective pressure for isothermal combustion, and is now using, I think, constant-pressure combustion, so that his diagram is like Fig. 118, a compression which goes very high—and which is the source of his high efficiency—followed by very short constant-pressure lines, and then an expansion to wherever he wants it. Whether that line (2–3) will be a constant-pressure line or an isothermal depends entirely upon how fast he feeds fuel, and, of course, on how cool the cylinder is allowed to get. The fuel can be fed so fast as to keep the pressure constant, or even to raise it. With a high pressure the efficiency is raised, and Fig. 118 differs from Mr. Frith's diagram (Fig. 117) only in the compression and the presence of a receiver-delivery line (*AB*), which is an accident of design not essential to the cycle as such.

As to the table in paragraph 10, to which objection was made, it is not worked out by any guess. There is referred to in paragraph 10 the Columbia School of Mines *Quarterly*, Nos. 1, 2, 3, Vol. XXII., 1901, and in those numbers will be found the mathematical analysis which leads to and justifies the table. I have a copy here; it is ninety pages of careful analyses, and was not, as I said before, arrived at by any accident. It represents a lot of

good hard work, put down in a systematic way, and that table is fully justified by what is therein contained.

If Mr. Brayton did go through most of the work of this paper, as Mr. Suplee states to be his belief, all I can say is that it is a pity no records were kept of that work.

The experiment mentioned of producing a sphere of flame is absolutely impossible with a mixture of air and gas in true chemical proportions; with excess of fuel and burning in air it is possible. The reasons and conditions are clearly set down in the body of the paper.

Mr. Frith.—Mr. Lucke's sketch of a Diesel card is one that was only occasionally obtained when the introduction of fuel was too rapid; its usual shape was a steep inclination, approaching the

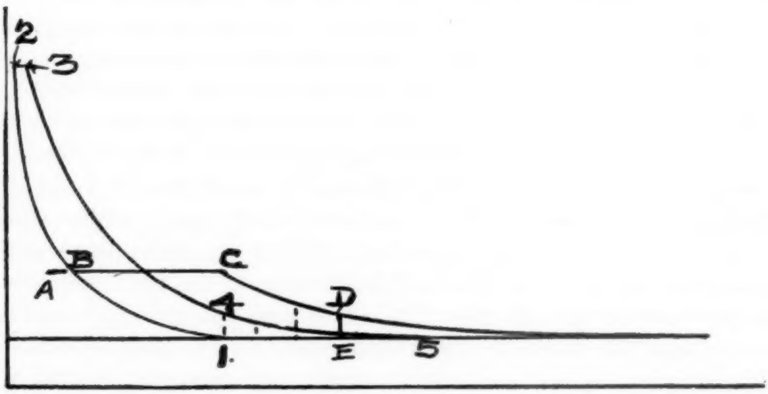

FIG. 118.

isothermal line of expansion. That it occasionally expanded horizontally does not establish any likeness to the Brayton cycle, where the gases are compressed in one cylinder and necessarily delivered into another; and I must decidedly dissent from his claiming a similarity between the Brayton and Diesel cycles. Why is not the latter nearer to being identical with the Otto cycle? In both, the gases or air are compressed in a single cylinder, the admission, fuel burning, and exhaust strokes being in the same rotation, though in the Diesel the fuel is added afterwards; and I do not doubt that Otto cards can be found which are, for a short distance, nearly horizontal at the top.

The doubt expressed in regard to the accuracy of the table is due to the position given to the Brayton cycle in respect to high

mean effective pressure; if—as one would judge by the samples shown of so-called Brayton cards—these mean effective pressures are figured from cards which do not show the line of *air compression and delivery* into a second cylinder, then they are misleading and, I think, misnamed, such cards not being recognized as representing the Brayton cycle.

Mr. Lucke.—I think we disagree chiefly in our definition of the word "cycle." I take as the definition of the word "cycle"—and I have defined it at the beginning of my work, as was proper, I think—"a series of operations performed upon and by a certain gas." I do not consider any machine involved in it at all. If a machine is constructed to carry out a certain series of operations upon perfect gas, or with a perfect gas, then I say that machine operates on that cycle. I am not considering the cycle as being represented by the machine, but the machine accidentally carrying out the cycle; and every other machine that may be represented as carrying out the cycle I will classify with it. The cycle is a series of operations performed upon a perfect gas or by the perfect gas. Consider the gas alone; then, in thermal operations of expanding and compressing, heating and cooling, it makes no difference whether those are done in one cylinder or in two cylinders so far as my definition of the cycle is concerned. And that seems to be the main objection to the agreement between the Diesel and the Otto, as shown. The Diesel engine compresses in one cylinder and expands in the same cylinder. The Brayton engine compresses in one cylinder and expands in another. So far as the mass of gas is concerned, it makes absolutely no difference which you do, for in each case two constant-pressure lines between two adiabatics may be obtained. I consider them to be the same cycle, and I think that is our chief disagreement.

Mr. Frith.—I think that is so.

*Mr. Lucke.**—This work is not presented as *the* solution of the heat-engine problem, but only as a report of some years of very careful work in the field; and it is hoped the contribution is not valueless in clarifying to some extent the nature of the questions involved.

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* Author's closure, under the Rules.

No. 924.*

TOPICAL DISCUSSIONS AND NOTES OF EXPERIENCE.

No. 144.—"WHAT DOES IT COST TO RUN TRAINS AT HIGH SPEED?" †

1. *Prof. F. R. Hutton.*—At a meeting of the Western Railway Club in January, 1900, a resolution was passed requesting the American Society of Mechanical Engineers to have the above matter "brought up for consideration and discussion in as thorough and complete a way as they may think fit." The Publication Committee believing that the subject was of broad interest to Mechanical Engineers, have directed that the request of the Western Railway Club be carried out by making this subject a topical query, with an Introduction by the Secretary which should present the summary of the original paper of Mr. F. A. Delano, together with references to the discussion, which was held at the meeting in Chicago, January 16th.

2. Mr. Delano's paper groups the items in the costs of operation, which are increased with high speeds, into the following six headings:

First.—Increased fuel consumption.

Second.—Higher grade or standard of machinery, material and service required for extra fast trains.

Third.—Increased wear and tear; cost of maintenance of machinery, permanent way, etc.

Fourth.—Increased risk of accident by breakage of machinery, injury to track, etc.

Fifth.—Increased risk of accident, such as collisions with other trains and the risks which have to be taken.

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* Presented at the New York meeting (December, 1901) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For previous discussions on this topic consult *Transactions* as follows:

No. 55, vol. ii., p. 524: "Railroad Economics." S. W. Robinson.

No. 485, vol. xiii., p. 359: "The Electric Railway as Applied to Steam Roads. B. J. Dashiell.

Also, *Railway Master Mechanic*, July, 1901, p. 212.

Sixth.—Delay to traffic on account of keeping the road clear for the high-speed trains.

3. As expanded by Mr. Delano, the considerations advanced under each heading, cover the following points:

First.—An accepted formula for train resistance, expressed in pounds per ton, which is in use by the Baldwin Locomotive Works, is in the form $R = 3 + \frac{V}{6}$, in which V is expressed in miles per hour. Therefore at 30 miles the train resistance would be represented by 8, while at 60 miles it would be represented by 13. Hence an increase from 30 to 60 miles per hour would raise the fuel consumption for power on the basis of 5 over 8, which is 62½ per cent. Mr. Delano observes, however, that the increased fuel consumption per car or per ton, is greater than this. In confirmation he calls attention to the fact that the class of engines which 10 years or so ago handled trains of 10 or 12 cars successfully, on many of our trunk lines, are now in use on branch and light service only, and notes furthermore the fact that engines of more than twice the power do not handle trains of equal length. Professor Goss calls attention to the fact that power is not alone tractive power, but is the product of tractive power into space passed over, and that taking the hour as the unit, the power in the two cases will be the proportion of 8 x 30 to 13 x 60, which is the ratio of 8 to 26. This means therefore a percentage increase of power of 18 on the basis of 8, which is 225 per cent.

This is further confirmed by the comparison of the present engine with the older engine, which shows the increase to be in boiler capacity, much more rapidly than in cylinder volume.

4. Mr. Delano's second point is intended to cover the extra expense which is incidental to the standard imposed by high-speed work in preparing the brasses, in burnishing journals, in using special grades of waste and oil, and in selecting coal. The locomotive itself is also taken in hand by the best and most expensive mechanics and in the Maintenance of Way Department, the standard set by the high-speed service, brings the whole staff up to concert pitch.

5. Mr. Henderson in the discussion spoke of the precautions which they had had to take on the Chicago and Northwestern, either in picking over the coal to get out slate and dust, and latterly in the use of forks for loading tenders, so that the fine

stuff would be thrown out and only the selection tossed into the bin. He further calls attention to the tendency to use excess of oil, both under cars and on the engine itself.

The third point is proved by the evidence where records of engines and boilers are kept. It has been found that the failures in passenger service are much greater in relation to train haulage, than the failures in freight service.

Furthermore, a new piece of track often receives damage from a heavy engine hauling a high-speed train, while it has stood up satisfactorily under a number of heavy slow-moving trains. Where the locomotive engineer is a believer in the injury done to rails and substructure from the hammer blow of the counterweight, it is apparent that the high-speed engine would have much more effect than the slower moving engine of greater tractive power, with a less path described by the counterweight in its single revolution.

6. *Fourth.*—The consequences of an accident either to machinery or track at high speed are much more serious both in the money loss and in the moral effect of such accident than those which occur to slow-moving freight trains. While it is true that eternal vigilance has reduced such accidents to comparative infrequency they cannot be entirely removed.

Fifth.—The fifth section includes not only the disaster of a collision, but further losses in indirect ways. Suppose a freight train has a certain limited time to get in on a side track, to clear the way for a high-speed train which needs the track. There may be a hot-box on the train requiring attention, but, with the limited time left to them, the box is allowed to go with possibly fatal results. It is the high-speed trains which are responsible for the expensive block and signal systems.

7. Under the sixth head Mr. Delano points out that it has been an axiom of the railroad managers that the way to do a maximum business over a piece of railroad is to have all trains moving at as nearly a uniform rate of speed as possible. A steam road handling long trains at intervals which are determined by the speed of the intermediate slow trains, cannot begin to do the business which is done by a slow-moving street car line, or elevated railroad with its frequent trains. The slow train may either follow the fast train, or a fast train follow a slow one. In either case there is a gap behind or before the slow train, during which time the railroad is unoccupied and earning no money.

This expense of operating the high-speed train is difficult to arrive at, yet must be fairly considered in treating the subject.

8. In the discussion of Mr. Delano's paper, Mr. F. H. Clark, of the Chicago, Burlington, and Quincy Railroad, presented a tabular result in the following form:

Train.	No. Cars.	Speed.	No. Stops.	Mileage.			Coal Used—Tons.	
				Train.	Car.	Total.	Per Day.	Per Car.
A	6.76	31.33	18	34,480	233,802	1,151.8	6.36	170.38
B	6.24	35.70	8	34,480	215,110	1,111.4	6.14	176.11
C	2.95	45.40	7	34,480	101,525	1,091.7	6.03	369.83
D	3.88	48.00	7	34,100	132,240	1,274.1	7.12	328.35

This result seemed to substantiate Mr. Delano's suggestion that for an increase of speed of about 53 per cent. there was an increase in coal consumption of 92 per cent.

9. E. E. R. Tratman presented a series of figures with the suggestion that these were averages only, but if similar figures could be secured for faster or limited trains exclusively, they might lead to changes and economies.

Repairs and supplies for engines and tenders, per mile run	4.66	cents
Engineer, fireman, wipers, etc., per mile run	7.29	"
Oil, waste, and tallow, per mile run	0.23	"
Fuel, per mile run	6.35	"
Total cost per mile run by engines	18.53	"
Run per ton of coal	22.84	miles
Run per pint of oil	15.40	"
Run per pound of waste	182.93	"
Cars per passenger train	4.75	cars
Cars per freight train (loaded)	16.87	"
" " " " (total)	22.92	"
Repairs of locomotives per mile run	3.25	cents
Engineer, firemen, and wipers, per mile run	0.87	"
Oil, tallow, and waste, per mile run	0.16	"
Fuel, per mile run	5.96	"
Run per ton of coal	28.78	miles
Cars per passenger train	4.95	cars
Cars per freight train	20.18	"
Repair of locomotives per revenue train-mile	5.60	cents
Repair of cars per revenue train-mile	7.97	"
Station service " " " "	11.25	"
Train " " " " "	7.23	"
Locomotive service per revenue train-mile	8.60	"

Train and station supplies per revenue train-mile	2.01 cents
Fuel per revenue train-mile	9.44 "
Oil and waste per revenue train-mile	0.47 "
All other expenses per revenue train-mile	44.66 "
Total operating expenses per revenue train-mile	97.23 "

In connection with these statements, Mr. Delano mentioned a statement which had been made to him, that instead of about a $1 a train-mile the cost of running limited trains was nearly $2. The figure given in the Interstate Commerce Report adds to the ninety-seven cents, taxes, interest, and other fixed charges, which brings the figure to $1.47, and that it would not be a very considerable increase in the elements covered by his enumeration, which would raise the figure to $2.

Mr. Wilfred Lewis.—I would like to ask, if there is any representative of the Baldwin Locomotive Works here, on what data the formula $\left(R = 3 + \frac{V}{6}\right)$ is based? We all know that journal friction in starting is about 15 per cent., and when the velocity is reduced to zero, the train resistance ought to be about 50 pounds to the ton for journals one-sixth the diameter of the wheels; but the formula suggested gives only three pounds to the ton, indicating less than one per cent. journal friction in starting. It would be interesting to know upon what data that formula was based, and whether it has not been superseded, because the principal elements which go to make up train resistance at constant speed on a straight and level track are journal friction and air resistance, and any formula which attempts to express the resistance of a moving train must combine the laws of journal friction and air resistance.

It is well known that journal friction decreases with increase in speed, and air resistance is generally believed to depend upon the square of the velocity, and not upon the velocity direct, as indicated by the proposed formula.

Mr. George L. Fowler.—I am not a representative of the Baldwin Locomotive Works, but it is my impression that that formula was based on the results of a long series of very careful experiments which were conducted by the Baldwin Locomotive Works on the trains of the Philadelphia and Reading Railroad between Camden and Atlantic City. The formula gives results somewhat less than the formula which is known as that of the *Engineering News*, which was adopted by Mr. Wellington, and

somewhat higher than a formula which was developed by Mr. Daniel Barnes, who was formerly a member of the Society and a resident of Chicago. The results obtained by the Baldwin Locomotive Works were the results of both dynamometer and indicated tests.

I may add that all these formulas of the *Engineering News*, Mr. Barnes, and the Baldwin Locomotive Works give results very considerably lower than does the old Clark formula.

Mr. L. R. Pomeroy.—In looking over the report made to the Master Mechanics' Association by Mr. Delano, the General Manager of the C. B. & Q. Railroad, I noticed that the costs given which could be definitely located showed an increase in coal consumption due to speeding up the trains.

The test referred to, described in the report, was made by Mr. Bush, S. M. P. of the C. M. & St. P. R. R., between Milwaukee and La Crosse, with trains similar in every respect. The speed was increased 25 per cent., yet the increase in fuel consumption was but 14 per cent., this being the only item which could be definitely located. Most of the other elements in the case were at best but approximations or shrewd guesses.

The fact suggests one point which has not been touched upon; namely, that the total cost for locomotive fuel is so small a percentage of the total cost of operation, that any increase in coal consumption would make a very slight showing in the total cost of operating, and would be not worth mentioning. For example, the total cost of fuel is about 7 per cent. of the total cost of operation per train mile. Suppose it cost 50 per cent. per train mile more for fuel to run fast trains, this increase would only amount to an increase of 3 per cent. per train mile in the total cost of operation; and likewise with repairs, which amount per train mile to only 4.7 per cent. of the total cost of operation.

The Chairman.—If there is no further discussion we will take up the next topic.

Mr. H. S. Haines.—I do not like to see this important subject passed by in a perfunctory way, for it is a matter of great practical value in the operation of railways to know what it costs to run trains at high speeds. I observed the title of this topic with great interest, and regretted when I looked through the discussion to find that there was so little of practical value in it. If this is to go forth as an authoritative expression of the views

of this Society, I fear that it will make an impression on the minds of those who read the discussion that its members know little about it, or are cautious about letting the public have the benefit of their experience and information. I think that the discussion would have been more profitable if the question had stated a little more definitely what is meant by high speed.

Trains on a railroad have to run at certain speeds. The question is, what is the ordinary rate of speed of a passenger train, and what does it cost to accelerate that speed? Then, what are the items which properly enter into the cost of that acceleration? If we are to accept the items as expressed in paragraph 2 of this statement, we may ask as to "increased fuel consumption," over what ordinary rate of consumption, and apply the same question to several of the succeeding items. If we seek a formula applicable to greatly accelerated rates of speed, we want something more than so simple a formula for train resistance. I even find that the formula given here for train resistance is not recognized in this Society as authoritative. There are references made to other formulas with which I am not familiar. My experience in such matters, extending over many years, has been of a practical character, and therefore I appreciate the value of formulas applicable to the cost of accelerated train speed, if given in such a way as to be of practical use. For this purpose it would be going very far afield to use the figures of the Interstate Commerce Report, for I doubt if any railroad manager would include taxes, interest, and fixed charges in ascertaining the cost of train service. If this discussion is to be published, let it contain something of value, or at least something which will lead to further discussion in technical periodicals and in other societies that are, perhaps, more directly interested in the subject.

There is another aspect of this subject which is of greater value to this country as a whole; that is, to ascertain the most economical rate of speed for freight service. I assure you that it is of much more value than to ascertain the cost of running passenger trains at high speed, for such speed is due to competition between railroad companies in which the cost of accelerating the speed is disregarded. I will express the problem which I have in mind in its simplest form :

Suppose a perfectly level railroad, 100 miles long, with an unlimited number of loaded cars at one end. What is the most

economical rate of speed at which such tonnage can be moved to the other terminus? It is a very simple question as I have put it; but, when you anaylize it, you will find that it involves many conditions with which I will not take up your time. I had occasion, in another society, to discuss the question of railroad competition with the Erie Canal, and found such a lack of information as to the most economical rate of speed for moving grain by rail from Buffalo to New York, that I thought the subject could be discussed with profit, not only to the railroads interested, but also to those who would be benefited by cheap grain rates from the Western grain fields to the Atlantic seaboard.

Mr. M. N. Forney.—This is a subject about which I have thought a good deal, and, as Mr. Haines said, it is an extremely complicated one. Of course, the condition of thé road is a very important consideration. With a poorly ballasted road and with light rails, running at high rates of speed is very expensive. The size of the engine, too, is an important factor. With an engine big enough to make sufficient steam and to handle the trains easily, you can make a higher rate of speed, economically, than you can with smaller engines which you are obliged to force. But the most important considerations, I think, are the other incidental expenses.

It used to be true that the wages of engineer and fireman on trains was about equal to the expenditure for fuel, on roads on which fuel was cheap. Recently the very great increase in train loads has probably reduced the expense of engineer and fireman relatively to the fuel, and now we can readily see that if, in one case, a train is run at 15 miles an hour, and in another is run at 30 miles per hour, at an increase of 5 per cent. for fuel, that in the first instance the cost of train service is doubled, because the men are on the road twice as long at the slow rate of speed as they would be if they were going at the high rate; so that the additional cost for train service is greater than the saving in fuel. The cost of train service is a very important item, and one which is very often lost sight of.

I regret that I did not prepare myself to say something better worth listening to, but must confess that I have not read the paper.

Mr. Carl G. Barth.—On the mathematical side of this matter, it may be well to suggest the futility of attempting to determine

with much nicety the maximum or minimum value, as the case may be, of a function which depends on so many variables whose values can be ascertained with only a limited degree of accuracy.

In a considerable field about the maximum or minimum value, such a function usually varies but little, so that all that it is possible, or indeed desirable, to do, is to ascertain this field within which, the true maximum or minimum value lies, and within which the function does not vary greatly from that maximum or minimum.

Now, in the case of transportation—both of passengers and goods—speed is certainly a desideratum aside from the question of mere economy; so that, on the whole, it appears to me that the true question is: How fast can we run our trains without overrunning the strict economy limit to an extent that will actually count?

No. 145.—Some Peculiarities of Springs. A Spring Testing Machine.*

10. *Mr. Stephen W. Baldwin.*—When a coiled spring is put under a car or similar vehicle, the character of the loading, or impact, on the spring is often such that the load is suddenly applied, and then suddenly released. The tendency of the spring is to cause the body of the vehicle to "teeter," until the effect of the applied load successively compressing the spring and allowing it to release itself is diminished by the disappearing of the vibrations. The flat, or leaf spring, as applied under carriages, locomotives, and elsewhere, by reason of the friction of the leaves upon each other, does not produce this same teetering effect, and for this reason is a preferable type. The room which the flat, or leaf spring occupies, and its greater weight and cost, are the objections to its use. It would obviously, therefore, be an advantage if a coil spring could receive from without some effect similar to the friction of the leaves on each other, whereby an impedence of its tendency to teeter could be caused, and its vibration could be made to conform more nearly to that of a leaf spring; with this attainment there are secured the advantages of less cost, weight, and room required, all of which are important.

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* For further discussions on this subject, see references with Paper No. 925 presented at the New York, December, 1901, meeting.

11. It has recently been observed by a firm of spring makers that a testing machine for springs could be devised whereby the application of the load upon a lever, which was counterbalanced by the spring, would cause that lever to trace the ordinates of a

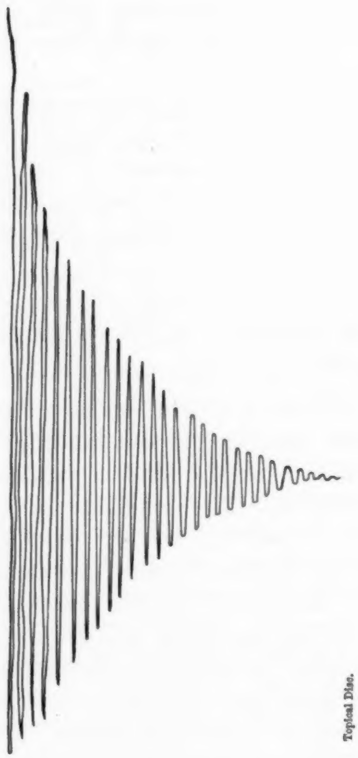

FIG. 119.—DIAGRAM FROM COILED SPRING.

FIG. 120.—DIAGRAM FROM FLAT LEAF SPRING.

FIG. 121.—DIAGRAM FROM IMPROVED COIL SPRING. IT WILL BE NOTED THIS DIAGRAM IS VERY LIKE THAT OF FIG. 120, FLAT LEAF SPRING.

curve, the paper being moved transversely at right angles to these ordinates while the lever was vibrating. Fig. 119 shows the diagram from a coiled spring of the ordinary sort tested in this way. It would appear from the character of the diagram and the method whereby its lines were drawn, that the curve through the extremities of these ordinates should be of a hyperbolic form. The height of the ordinates appears to vary inversely as the abscissas which are proportionate to the times. The mathe-

matical analysis which brings out this result is aside from the present purpose, but it will be apparent that the stiffer the spring the less will be the amplitudes of the vibrations, and that the greater the deformations the longer it will be before the spring comes to rest. It would appear, therefore, that as a spring lost its life, in the technical sense of that word, the form of the diagram would alter.

12. Two practical questions are therefore suggested by this method of testing and the diagrams which it presents. The first is: Can the adaptability of a steel for spring purposes, either as the result of its chemical constitution or its heat treatment, be inferred from the form of the diagram which it would give when tested by this method, and by the making of such a record? Second: Would the modification of the diagram caused by fatiguing a spring by test in the ordinary type of impact machine give a further and satisfactory indication as to the wisdom and adaptability of a certain manufacturing process or quality for springs? It is believed that the scientific question, resting so closely upon a practical basis, which is involved in the foregoing discussion, should bring out interesting results.

13. The diagram which is shown in Fig. 120 is a reproduction of the form of diagram from a flat, or leaf spring, where applied friction impedes the tendency to vibrate. Not only is the number of vibrations much less, but the time covered and the space passed over by them are noticeably less.

The improved coil spring, an action diagram of which is shown in Fig. 121, is made as shown in Fig. 122.

Two flat steel plates, about $\frac{3}{16}$ of an inch thick and of a width a little more than the outside diameter of the spring, are bent U shape. These plates are made of moderately high carbon steel and are tempered. One slips over the top and the other the bottom of the spring, the ends lapping past each other about 4 inches. The top plate is formed to receive the load in the centre, producing a tendency to open or spread apart the lower ends of the plate.

The lower plate is formed to receive the load near the outer sides, producing a tendency to close the upper ends of this plate against the lower ends of the top plate.

In this way a rubbing friction is produced which has much the same effect as the friction between the plates of a leaf spring, with the result that the action and diagram of this spring are

very like the action and diagram of a leaf spring, which is the object sought.

Thus the action of a leaf spring is secured by the improved coil spring at a lower first cost, less weight, and less requirement for room, all of which are important objects to attain.

It would seem that by the use of the testing machine and diagrams, the spring maker and spring user have a means at hand to easily make tests and graphic records showing the effects of different form of springs, different working, grade of steel, the action of old springs as compared to new, and thus secure much valuable information for both maker and user.

Mr. Albert A. Cary.—In considering the motion of a mass, if we

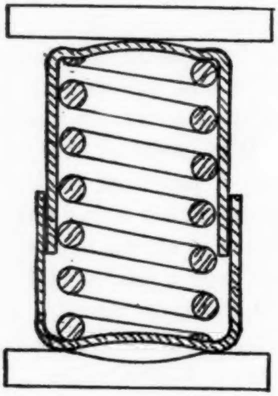

FIG. 122.

find that after a certain definite period of time the mass always returns to the same position, and if we find this mass at the times of observation always moving in the same way, we have what is defined by physicists as a simple harmonic motion.

To apply this definition to the case before us, let us draw a horizontal line through the vertical ordinates shown in Fig. 119, so that it will pass through the recorded point where the oscillating motion of the spring finally ceases. By measuring the distance from one ordinate to the next alogn this line we will find an almost uniform distance of $\frac{1}{16}$ of an inch or $\frac{1}{8}$ of an inch where every second ordinate is measured, and whatever variation is found in this measurement can doubtless be attributed to inability of the recording device used to accurately write an exact record of the oscillating motion. The horizontal line just

described, represents the position of the weight (W) used to load the spring when it is at rest, as shown in Fig. 124.

Now let us load the spring shown in Fig. 124 until the weight (W) descends to the position shown in Fig. 125. The moment we suddenly release this added weight, the just previous statical condition is lost, and the elasticity of the spring draws the

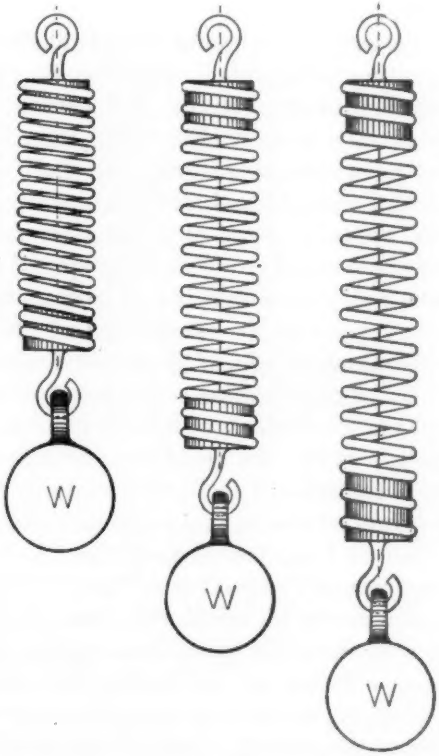

FIG. 123. FIG. 124. FIG. 125.

weight back to its former position, as shown in Fig. 124; but as W when reaching this position possesses kinetic energy, it continues its upward movement until this energy is expended, when the weight—which in this last position (see Fig. 123) possesses potential energy—descends, and on reaching the position shown in Fig. 124 has acquired new kinetic energy sufficient to carry it downward again toward the position shown in Fig. 125, whence it starts upward again, as has just been described; thus,

with alternating conditions of kinetic and potential energy, the weight continues to oscillate up and down, as we have seen illustrated in Fig. 119. As has been shown from Fig. 119, the weight (W) passes its position of rest, *i.e.*, where it would remain, under statical conditions, as shown in Fig. 124, at exactly equal intervals of time, as indicated by measurement along the horizontal line, and therefore we have a simple harmonic motion.

Now consider another example of simple harmonic motion as found in a vibrating pendulum. Suppose we take a position so that our eye is directly beneath the centre of the "bob" when hanging at rest, as at E (Fig. 126); then by looking upward when the pendulum is vibrating we shall see the "bob" *apparently* moving backward and forward in a straight line from W to W' on the opposite sides of its statical position of rest (C), in precisely the same manner that our spring weight moved. According to the well-known first law of motion, this pendulum, after once beginning to vibrate, would continue to move forever through its original amplitude, if it were not acted upon by retarding forces. But, due to friction at the point of suspension and the resistance of the air through which the pendulum moves, the amplitude through which the pendulum swings gradually decreases, although the time of oscillation remains constant, until finally the pendulum comes to rest; and an autographic record of its motion, had it been traced from the "bob" on a sheet of paper moving upward behind the "bob," would produce a series of lines practically identical with that shown in Fig. 119.

What I have said about the pendulum applies directly to the spring. After once being set in motion, the weighted spring would forever continue to oscillate were it not for the opposing forces of friction of the air and other resistances. One of these resistances to oscillation in the helical spring is largely due to the manner in which its ends are supported, which methods of support prevent the bar or wire composing the spring from turning freely around its own axis torsionally.

A helical spring, either for extension or compression in order to be theoretically perfect in its application, should have the bar or wire composing it held securely at one end, and this bar should be allowed to turn freely about its own axis from its secured end to the opposite free end, the same as a perfectly suspended shaft twists torsionally from one (the driven) end to

the other (driving) end. Such an ideal condition is much further departed from in springs which resist compression than in those resisting extension. In compression springs we often find both ends broadly flattened and ground off square, so that under load not only one but both ends of the bar are secured from torsional turning. The upper squared end thereby tends

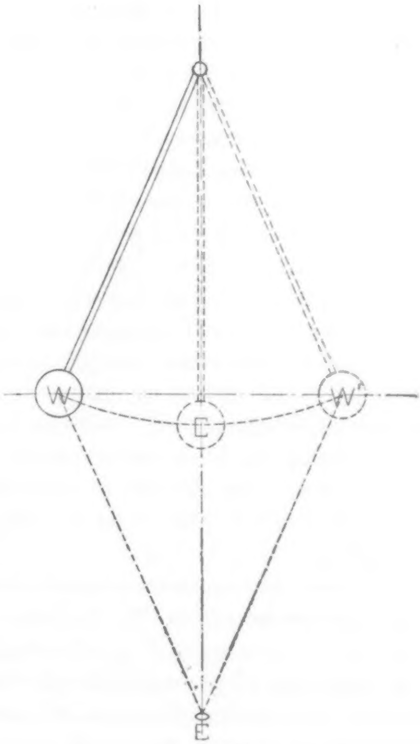

FIG. 126.

to check the torsional movement in the bar and thus restrain the oscillating movement. The effect of this securing *both* ends of a compression spring is to transfer all torsional movement in the bar composing the spring to the central portion (*i.e.*, between its ends), the same as a shaft is twisted in both directions when the driving pulley is placed at some position between its ends and driven pulleys are placed one on each end of the shaft.

Another fault frequently found in the use of compression springs which tends to check their free oscillation is uneven

loading. When a spring of this kind is in operation, the centre of gravity of its load should move directly along the centre line or axis of the spring, otherwise the spring will be unequally compressed at opposite sides, frequently causing it to "buckle" sideways. The result of such unequal straining will be more or less material interference with the free and even oscillation of the spring. Frequently we find the ends of springs carelessly finished, so that as the load is applied the spring bends and buckles, also causing unequal stressing throughout the bar of which it is composed, and this fault will cause an uneven oscillation and further tend to retard the vibration.

Another fault sometimes found in the application of compression springs is that they are enclosed either partially or wholly in a cylindrical case which has a diameter but little larger than that of the unloaded spring. I have frequently seen the ends of compression springs held in such cup-like cylinders. As the spring is compressed, the closing of the coils causes the diameter of the spring to increase, and thus, as the coils rub against their enclosing cylinders, their free motion is retarded materially, especially when such cylinders grasp the spring firmly before the compression is completed. All these and many other causes met with in spring applications check the free oscillation of the spring and tend to bring it more or less quickly to a position of rest, or, in other words, they tend to destroy the perfect functions of the spring.

With these statements before us we are now ready to consider the two practical questions which Mr. Baldwin says are suggested by this method of testing and by the diagram presented. I cannot see how this method of testing is of value to show the adaptability of steel for spring purposes, either as a result of its chemical constitution or as to the heat treatment it has received. The chief value of this diagram seems to be in showing how far from perfect the performance of the spring is, and as the causes which prevent free oscillation are removed, to show the improvement thus obtained. The nearer this diagram approaches a series of vertical ordinates of equal length, the more perfectly the spring is performing its function.

There seems to be a very common idea that by tempering steel wire its modulus of elasticity (in tension or in torsion) is changed. This is a mistake, as the modulus remains constant; but the most important change obtained by tempering is a

very material increase in the elastic limit of the wire. To illustrate this, should we take two pieces of wire from the same coil, and alike in all respects, and test one in a torsional testing machine while the wire is soft, and afterward test the other piece, which has been through a tempering process, we shall find that the torsional resistance is identical in both cases if tested under exactly the same conditions; but it will be found that the angle of twist which can be safely applied to soft wire test-pieces before the elastic limit is reached is small compared with the angle of twist which the tempered piece can sustain before *its* elastic limit is reached.

Without a knowledge of these facts, which I have proved in a number of tests, many think that the torsional resistance for each degree of twist is considerably greater in the tempered piece of wire than it is in the soft piece within their elastic limit; if this were true, such a method of testing as is described by Mr. Baldwin might give some information as to the superiority of one method of tempering springs over others.

Again, as various qualities of steel are used, some may think that there is a change in the modulus of elasticity. Experiment has not verified this assumption for me, but I have found that a change in the amount of carbon present makes a material difference in the elastic limit of the wire and in its ultimate shearing stress. With these facts before us I question whether the records obtained from the testing device shown would be of as much value as records obtained from a torsional testing device such as I have used in testing the wire before the spring was made.

It is almost impossible to make all springs exactly alike in pitch, diameter, etc., and all variations in the spring itself would be recorded by this method of testing; and should we assume, for argument's sake, that variations in physical and chemical qualities of the bar or wire would produce a change in the shape of the diagram, these would be added to the variations produced by the dissimilarity found in the dimensions of different springs, commercially supposed to be alike, as well as variations in the method of loading, which would be apt to produce a misleading diagram.

In regard to the second question suggested by Mr. Baldwin, concerning "the modification of the diagram caused by fatiguing the spring by test in the ordinary type of impact machine, giv-

ing further and satisfactory indication as to the wisdom and adaptability of certain manufacturing process or quality of springs," I am afraid I do not wholly grasp his meaning. In a *perfectly* tempered spring, made in good proportions and containing a high grade of spring stock, there should be no fatiguing, and such a spring should have the same endurance after being subjected to a blow as it did before, providing it has not been strained beyond its elastic limit. Such perfect springs require a most careful process of manufacture, but I have produced them for customers who have been willing to pay a good round price. The average well-made, good quality springs, such as are ordinarily obtained from first-class spring makers, will generally take a certain amount of set at first; but after receiving one or two sudden compressions under an overload they should remain unchanged for an indefinite period of time.

Springs which will not take a set under such compressions must be made of a steel running comparatively high in carbon, and the tempering process used in manufacturing them is a very delicate manipulation. For a great majority of purposes it is not desirable to use so high a grade of steel, as springs made from it are more apt to break in use and not to be uniform when a large number are required. It is therefore better to use a considerably lower grade of steel, which will permit of a less careful tempering process being used.

It is very interesting to note that the diagram in Fig. 119 shows a greater amount of motion during the oscillations of the spring above the horizontal line I have mentioned than it does below. To all appearances this record starts at the top of the left-hand ordinate, and unless the record is made in the reverse direction to that travelled by the spring, I should say that this diagram is printed upside down. By reversing the diagram there will be recorded exactly the motion I have described in the first part of my discussion in connection with Figs. 123–125.

With the diagram thus reversed (See Fig. 127), oscillation begins at the lower right-hand corner of the diagram, with the paper on which the record is written moving towards the right, and when the additional weight shown in Fig. 125 is released, the spring suddenly draws the weight upward, as I have before described, tracing the first (right-hand) ordinate. In case a compression spring was used instead of an extension spring with its suspended weight dropped below its point of support, the

record with the weight in this position would be identically the same. Assuming that my supposition is right (that this diagram should stand in a reverse position), it might be easy to account for the greater length of the downward stroke below the horizontal line, as in such a case when the weight was descending, it would have the accelerating force of gravity drawing

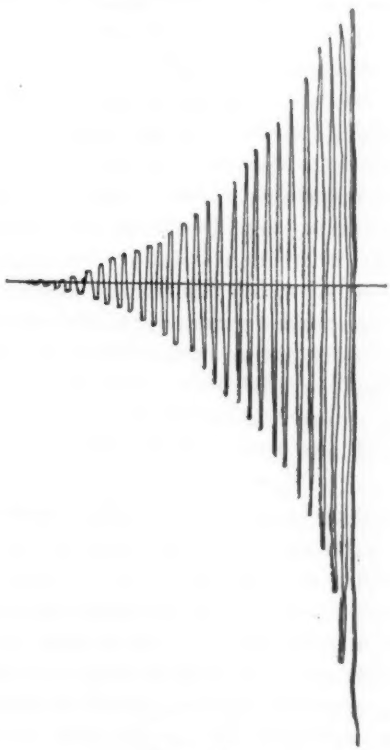

FIG. 127.

it downward; but when the weight is moving upward, this force would be a retarding one, and thereby a difference in the length of the ordinates above and below the horizontal line would be shown, as is the case in this diagram. Again, we may find greater retarding forces restraining the vibrating motion of the spring at one end of its oscillation than at the other, and such a set of conditions would affect the diagram in the way we find recorded.

In the diagram of Fig. 120 we find the functions of a perfect

spring very thoroughly suppressed. There is no form in which a spring can be made which is less satisfactory in its working than a leaf spring, and, I might add, that whenever it is possible to avoid the use of a spring made from flat wire or flat bars, and substitute a round-bar spring of the helical shape, do so by all means.

When I was interested in the manufacture of springs, a number of years ago, out of a lot of 10,000 helical springs sent out for various uses, there might be trouble or breakage occurring to ore or possibly two, but complaints received from users of a like number of springs made from flat wire were many times as frequent. The friction between the adjoining metal surfaces composing flat-wire springs, whether they are in the shape of leaf springs or spiral springs (such as are used in clocks), is very considerable; with such friction the comparatively thin flat bars or flat wire, of which the spring is composed, are constantly being worn out and weakened, and this friction constantly interferes with the perfect free movement of the spring in doing work. Springs made of flat bars or flat wire are much more difficult to temper evenly than those made from round or square wire, and are less able to stand sudden shocks or blows or injury of any kind.

Mr. Baldwin speaks of the undesirable tendency of springs to oscillate after a sudden load is applied, and he also mentions the objection to this oscillation. I have heard this objection complained of many times during my connection with the spring business, and while there had an opportunity to see many devices used to overcome this troublesome oscillation. Among those used on compression springs, I found that one customer, after allowing the spring to be compressed, would load it still further. This was done by placing a washer on top of the compression spring and then running a bolt through its centre, which bolt passed through a lower washer forming the bottom support for the compression spring. By tightening this central bolt an increased load was added to the regular load carried by the spring, and when a sudden additional load was thrown upon the spring the oscillations were much reduced.

Another device used with a compression spring to reduce the oscillation was a small spring placed inside of the coils of the large one, so that the springs were concentric one to the other, similar to "nested" springs. The inner spring was made shorter

than the outer one, so that when the blow was received by the outer spring the load would descend upon the inner spring, and additional force would be required to further compress both springs, thereby soon destroying the oscillation. I have seen, in place of this short inner spring, a rubber spring used so that the load after compressing the steel spring a short distance would strike upon the solid rubber spring with similar effect to that just described.

Another device for this same purpose was made by winding coils of square rubber between the coils of the steel spring, so that instead of compressing freely when the additional load was applied, the coils of the steel spring compressed upon the coils of rubber between them. This last method is not one which I would recommend, and is merely mentioned as being a device I have seen used.

Perhaps one of the most effective ways of preventing oscillation in the working of a compression spring is found in door checks, such as are used for closing doors. In certain devices of this kind the compression spring is enclosed within a cylindrical case carrying a tight piston upon its upper end which fits the cylindrical case tightly. When the door is opened this piston is drawn back into the cylinder, the spring is compressed under it, and certain valves allow a free admission of air between the piston and its end of the cylinder; but as soon as the spring starts to close the door, and the compression spring starts to regain its unstrained position, the valves admitting the air into the cylinder are closed automatically and a small air outlet allows the air to escape slowly, the size of the outlet being made in proportion to the speed with which the spring is supposed to close the door. I have seen this same device used for other purposes, and, in some cases, oil or glycerine is used in place of air. This is nothing more or less than a dash-pot arrangement similar to that used in connection with Corliss valve motions.

Prof. Albert Kingsbury.—The speaker says that he has proved by tests that the modulus of elasticity is not changed in tempering, although the elastic limit is changed considerably. I have recently had occasion to look for published data on this point; I have succeeded in finding nothing of importance in print in regard to the coefficients of elasticity of steel as affected by tempering, and I am sure that if the speaker has data upon this point it would be interesting if he would publish the facts. To

the average engineer the modulus appears to be increased by the tempering.

Mr. Cary.—I am sorry to say that, at the time I was connected with the spring business I have mentioned, I did not appreciate the value of keeping data as I do now.

In my early experiments to determine the value of the torsional modulus of elasticity for use in spring formulæ, I began by taking pieces of *tempered* straight wire from the same material that would afterwards be used in making the springs. Afterwards I experimented with the same material, only using soft steel instead of tempered, and found that I obtained the same results; and, further, I found almost identical results were obtained from tests of the various qualities of steel used in spring making; I therefore settled upon practically a definite value for my torsional modulus of elasticity.

All further torsional testing of steel spring material by me was simply to determine the limit of torsional elasticity, which varied with the quality of steel used and the method or degree of tempering, and for this work the test bars were straightened and then tempered in identically the same manner that the spring would be tempered.

I am sorry to say that I have none of that data available now, but there were tests made at the Watertown Arsenal, which are on record in our *Transactions*, giving identically the same results as those obtained by me.

Prof. Albert Kingsbury.—Among other records I have examined those of the Watertown Arsenal, and have found in those reports no experiments on the moduli of elasticity of tempered steel.

Mr. Cary.—The tests to which I referred, made at the Watertown Arsenal, in which it was found that tempering steel does not affect its modulus of elasticity, were presented in a paper on "Helical Springs," by John W. Cloud in vol. v., *Transactions A. S. M. E.* page 173.*

Certain experiments have been made in England which confirm my results. I am sorry to say I cannot refer to them directly at this time, but they will be found quoted in Prof. John Perry's work on "Applied Mechanics."

* Since the meeting, I have found further reference made to this matter in the *American Machinist* of May 4, 1899, page 378, in which Robert A. Bruce, in his article on "The Deflection of Helical Springs," and also the editor of the paper, make a similar statement.

No. 146.—The Linvolpon System—A Suggestion for a New Decimal System of Measurements Based on an Old Unit.*

14. *Mr. F. F. Nickel.*—The main objection to the metric system lies in the fact that all our standards are in inches and fractions thereof, and the cost of changing them would be enormous.

The new system should therefore not change our sizes, although it may change the names and figures in which they are expressed, and it is the object of this paper to show a way in which this may be accomplished.

15. The idea is to adopt the length now known as one-eighth of an inch as a basis; ten of these units, equal to $1\frac{1}{4}$ inches, would be taken as *The Unit* and given a proper name, for which I suggest Lin (from lineal). By adhering to the prefixes used in the metric system we can then readily form the subdivisions, as the following table will show—the last one is obtained from a combination of the two words mile and lin:

Inches.	Millilins.	Centilins.	Decilins.	Lins.	Dekalins.	Hektolins.	Kilolins.	Milin.
.00125	1							
.0125	10	1						
$\frac{1}{8}$	100	10	1					
$1\frac{1}{4}$	1,000	100	10	1				
$12\frac{1}{2}$		1,000	100	10	1			
125.	= 10.417 feet.		1,000	100	10	1		
1,250.	= 104.17 "			1,000	100	10	1	
125,000.	= 10,417. " = 1.973 English mile.						100	1
		1. foot.		9.6				

$$5 \text{ centilins} = \tfrac{1}{16} \text{ inch.}$$
$$2.5 \text{ " } = \tfrac{1}{32} \text{ "}$$
$$1.25 \text{ " } = \tfrac{1}{64} \text{ "}$$

hence, we can express all dimensions we are now using equally well in the new system, and there is no necessity of changing anything but the figure and the name.

The dekalin is $\frac{1}{2}$ inch longer than the foot, so we will have a

* For previous discussions on this topic consult *Transactions* as follows:
No. 4, vol. i., p. 29: "The Metric System." Coleman Sellers.
No. 26, vol. ii., p. 80: "Standard Measurements." George M. Bond.
No. 721, vol. xviii., p. 492: "The Metric System Versus the Duodecimal System." George W. Colles.

new rule, constructed exactly like the old two-foot rule, only 25 inches long.

16. Areas would be measured by the unit SQUARELIN, which is the area enclosed by a square whose side is equal to one lin.

The subdivisions would be as follows:

1 square milin	=	3.893 square miles (English).				
1 square kilolin	=	1,562,500.	sq. in.	=	10,851.	sq. ft.
1 square hektolin	=	15,625.	" "	=	108.51	" "
1 square dekalin	=	156.25	" "	=	1.0851	" "
1 square lin	=	1.5625	" "			
1 square decilin	=	.015625	" "			
1 square centilin	=	.00015625	" "			
1 square millilin	=	.0000015625	" "			

17. For measuring volumes, a cube whose side is equal to 1 dekalin could be adopted as unit and given a new name, for which I suggest VOL (from volume).

1 kilovol	=	1,953,125.	cubic inches.	
1 hektovol	=	195,312.5	" "	
1 dekavol	=	19,531.25	" "	
1 vol	=	1,953.125	" "	= 8.455 gallons.
1 decivol	=	195.3125	" "	
1 centivol	=	19.53125	" "	
1 millivol	=	1.953125	" "	

18. The weight of one vol of distilled water at greatest density would be properly the unit of weight, and could be called KILOPON (corrupted from pound).

1 kilopon	=	70.55	pounds avoirdupois.
1 hektopon	=	7.055	" "
1 dekapon	=	11.3	ounces "
1 pon	=	1.13	" "
1 decipon	=	49.4	grains.
1 centipon	=	4.94	"
1 millipon	=	.494	"
14.2 pons	=	1	pound.

These tables do not lay any claim to accuracy, the intention being to show the approximate relation rather than confuse by long rows of figures.

19. Having now outlined the idea, I wish to add a few tables to show how easily measurements given in the linvolpon system may be converted into values of the metric system. It will be noted that the constants used are 3175, 3175^2, 3175^3, or recip-

rocals thereof, disregarding the decimal point. I also suggest abbreviations for the different names:

LIN.

ml. Millilins.	cl. Centilins.	dcl. Decilins.	l. Lins.	dkl. Dekalins.	hl. Hektolins.	kl. Kilolins.	Milin.	Metric System.	
1			001					.03175	millimeter.
10	1		.01					.3175	"
	10	1	.1					3.175	"
		10	1					3.175	centimeters.
			10	1				31.75	"
			100	10	1			3.175	meters.
			1000		10	1		31.75	"
						100	1	3.175	kilometers.
			31.5					1	meter.

SQUARE LIN.

sqml. Square Millilins.	sqcl. Square Centilins.	sqdcl. Square Decilins.	sql. Square Lins.	sqdkl. Square Dekalins.	sqhl. Square Hektolins.	sqkl. Square Kilolins.	Square Milin.	Metric System.	
1			.000001					.001008	sq. mm.
100	1		.0001					.1008	"
	100	1	.01					10.08	sq. millimeters.
		100	1					10.08	sq. centimeters.
			100	1				1008.	"
			10000	100	1			10.08	sq. meters.
			1000000		100	1		1008.	"
						10000	1	10.08	sq. kilometers.

VOL.

mv. Millivols.	cv. Centivols.	dcv. Decivols.	v. Vols.	dkv. Dekavols.	hv. Hektovols.	kv. Kilovol.	Metric System.	
1			.001				32.006	cubic centimeters.
10	1		.01				320.06	" "
	10	1	.1				3.2006	liters.
		10	1				32.006	"
			10	1			3.2006	hektoliters.
			100	10	1		32.006	"
			1000		10	1	320.06	"
			3.125				1	hektoliter.

Pon.

mp. Millipons.	cp. Centipons.	dcp. Decipons.	p. Pons.	dkp. Dekapons.	hp. Hektopons.	kp. Kilopon.	Metric System.
1			.001				32.006 milligrams.
10	1		.01				320.06 "
	10	1	.1				3.2006 grams.
		10	1				32.006 "
			10	1			320.06 "
			100	10	1		3.2006 kilograms.
			1000		10	1	32.006 "
			31.25				1 kilogram.

In the following I will give a few of our new constants :

Pressures : 1 atmosphere = 3.26 hektopons per sql.
100 pounds per square inch = 22.2 hektopons per sql.

Weights in kilopons per vol are, of course, equal to the specific gravities.

1 vol of cast iron weighs 7.25 kp.

1 horse-power = 75 klp. (kilolinpons) per second.

1 P. C. Thermal Unit (Pon-Cent.) = 13.3 klp (that is, 1 P. C. Thermal Unit is the quantity of heat that must be imparted to 1 pon of water to raise its temperature from 0 degree to 1 degree Cent. and its equivalent of work is 13.3 kilolinpons).

1 klp (Kilolinpon) = 1.016 Kilogrammeters.

1 klp = 7.35 foot pounds.

20. All dimensions on drawings should be given in decilins. It is then only necessary to reduce the number of inches to eighths in order to obtain the new figure. For instance,

$$19\tfrac{3}{4} \text{ inches} = \frac{158}{8} \text{ inches} = 158 \text{ decilins.}$$

$$3\tfrac{15}{16} \quad \text{"} \quad = 31.5 \text{ decilins.}$$

Figures given in inches and decimals are simply multiplied by 8. For instance,

No. 1 B. & S. Wire = .2893 inch diameter.
.2893 × 8 = 2.3144 decilins diameter.

Or, if expressed in mils, we multiply by .8, and obtain the new dimensions in millilins. For instance,

289 3 mils = 231.44 millilins.

Mr. George W. Colles.—This is one of those numberless new "systems" with which the imaginative brains of their inventors are as generous as a smith is with the useless sparks which fly about his anvil. Were it possible for them ever to come into use, we should have such a jargon of systems as would make Babel hide its head in clouds for shame. Fortunately, however, the conservatism of mankind is too ponderous to be stirred by any such Lilliputian leverage.

Some years ago I had the honor to present to this Society a paper on weights and measures, in which I attempted to draw many valuable lessons from the history of the subject as to what our course should be in future, among the principal of which was the extreme danger of introducing ill-considered innovations. *That* history amply proves; and has proved on every occasion, that such a procedure invariably results only in plunging those whom it is desired to benefit deeper and deeper into the mire. "Tinker" with the currency if you may, and with the tariff if you must, but "*No tinkering with our weights and measures!*" should be our watchword here. It is the easiest thing in the world to concoct schemes *ad libitum* or *ad nauseum*, every one to his taste and to others' distaste; it is not of them that there is any lack; on the contrary, it is to reverse the Gulliverian plan, to make but one scheme grow where two, or a hundred, grew before—here is our task, here the problem which awaits solution.

The difficulty under which all such schemes as the "Linvolpon" system labor is that they approach the question without due consideration of what has gone before. A system which grows up in a night, like Jonah's gourd, must, like it, wither in the morning. No system which is drawn up with a single view to usefulness to a draughtsman in laying out drawings can aspire to general adoption; still less can one which is merely arbitrary and based on a fanciful and arbitrary handling of units. The more such schemes are proposed, the more will the true and main issue become obscured, and the more difficult will it be to effect any actual change at all. As an illustration of this, I refer to the agitation over decimal currency in England about the middle of the last century, described at some length in my paper above referred to.* In this case the chances

* "The Metric *vs.* the Duodecimal System," No. 721, vol. xviii., p. 492.

of success would have been much greater had there been a less diversity of schemes clamoring for acceptance by which the decimalization should be carried out.

I will not here enter into a specific discussion of the "Linvolpon" system further than to remark that, in taking the eighth part of an inch as his unit and decimalizing everything upon that, the author obliterates *all* existing units. The machine draughtsman and tool-maker, who are accustomed to use eighths of an inch, might find this scheme acceptable, though it is not clear why it would not be better to start from the inch and decimalize that, as is now frequently done, if decimals are preferred to octonary divisions. However, supposing this scheme acceptable to the draughtsman and machinist because they use eighths of an inch, it is still feared that the watchmaker, the railroad man, the land surveyor, the weigher, the gauger, and numerous other professional men—not forgetting entirely the every-day man, by which is understood about 99 per cent. of the population, who care nothing about eighths of an inch, and still less about "lins," "vols," and "pons"—would set up mighty objections to having all their units summarily dispensed with to suit the convenience or fancy of the draughtsman or tool-maker; while, unless others adopted them also, it is to be feared that the latter would find it impracticable to adopt them themselves. In thus making the world turn around the drawing-table, they commit the same error as the metric philosophers, who made it turn about the Paris meridian, with this difference, perhaps, that, while the former show a partiality towards one class of the population, the latter disfavored all alike.

It is a fundamental requisite of any really successful plan, or one worthy our serious consideration, that it be drawn up from a broad view and knowledge of all the past history of weights and measures, and especially that of the metric system, during the last hundred years. Its author must be careful to avoid the pitfalls into which the authors of that system fell—among the principal, indeed the very first, of which is radicalism. No system which involves radically new units can be considered. None which involves new names of the principal units can be considered. Our conclusion necessarily is, that the range of possible change of our present system is extremely limited, and that even that ought not to be made except with the utmost caution.

It was with the object of discovering the true and proper solution of the problem that I undertook the paper above mentioned; but the paper was of necessity largely confined to the metric system. It was pointed out, however, in the paper that our present system is in reality but a ruin of a remarkably well-ordered system, which has been allowed to fall into neglect, and that it needs only to be restored by judicious and careful strokes to appear, like a painting of Titian rescued from obscurity and decay, in all its original beauty and excellence. It has been, and still is, my intention—if time should permit, and if no one else will do so—to show what these strokes are, and how, by moderate changes, we may obtain a coördination of our present units to surpass in beauty, elegance, and utility (in my opinion) that of the metric system; for, as pointed out in my former paper, our system is a mixed octonary and duodecimal one, and these relations are in general more useful than the decimal. And all these proposed changes would be, it is hoped, within the range of feasibility, without too great a disturbance of national convenience. For the present, I leave the subject untouched, merely pointing out to would-be improvers the path which they must necessarily follow in order to achieve success. All artificial and arbitrary systems must perforce go the way of their predecessors, sinking into oblivion and becoming, in the words of the poet,

"A dust of systems and of creeds."

No. 925.*

EXPERIMENTS ON SPIRAL SPRINGS.†

BY CHAS. H. BENJAMIN, CLEVELAND, O.
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(Non-Member.)

1. THE experiments described in the following paper were made under the direction of Mr. French, and the calculations are his. There is such scarcity of reliable data on spiral springs, their strength and elasticity, that it seems desirable to publish the results of these experiments.

Our text-books and our technical journals contain discussions and formulas, but very few data from which constants can be obtained to use in the formulas.

2. In the experiments to be described, an attempt has been made to determine the coefficient of torsional elasticity and the safe stress for different sizes of bar and different ratios of mean diameter of spring to diameter of bar.

The following notation will be used:

P = load in pounds.
S = shearing stress in pounds per square inch on outer fibre.
G = coefficient of torsional elasticity.
D = mean diameter of spring in inches.
d = diameter of bar in inches.
H = height of spring in inches.
L = length of bar in inches.
x = deflection in inches with load P.

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* Presented at the New York meeting (December, 1901) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For previous discussions on this topic consult *Transactions* as follows:
No. 122, vol. iv., p. 335: "Spiral Springs." Oberlin Smith.
No. 173, vol. v., p. 173: "Helical Springs" Jno. W. Cloud.
No. 613, vol xvi., p. 92: "A Graphical Method of Designing Springs." G. R. Henderson.
No. 680, vol. xvii., p. 340: "Spring Tables." G. R. Henderson.
No. 914 (advance), to be presented at the New York, December, 1901, meeting.

Then, by the usual formulas for tension and compression springs:

$$P = \frac{S\,d^3}{2.55\,D} \quad \text{and} \quad x = \frac{L\,D\,S}{G\,d}.$$

3. The springs tested were all made of tempered steel and were open-coil, or compression springs. The results shown in the table were in every case obtained by testing a number of springs made as nearly alike as possible, and using the average loads and deflections for computation.

Every spring was first closed solid, coil to coil, several times in a hydraulic press, to remove all permanent set; then placed in a Riehlé testing machine and tested for capacity and corresponding deflection.

To illustrate, take for an example group No. 1 in the table. This group consisted of 15 springs, 9.25 inches outside diameter and 17.25 inches free height before closing. The steel used was 1.3125 inches in diameter and 150 inches long before the ends were tapered. These springs were placed in the press one at a time and closed coil to coil twice under the full capacity of the press, 75,000 pounds. The pressure was then removed, and upon measuring they were found to average 15.25 inches in height, showing a set of 2 inches. They were then closed twice more, but took no further set. A spring closed solid with 100 per cent. overload should take all its permanent set with two closings.

The springs were then placed in the testing machine and the load and total deflection measured. The average load necessary to close them was found to be 10,900 pounds, and the corresponding deflection was 7.0625 inches. When taken from this machine the free height was again measured, but they had taken no more set.

4. For substitution in the formulas we then have:

$$P = 10{,}900.$$
$$d = 1.3125.$$
$$D = 9.25 - d = 7.9375.$$
$$x = 7.0625.$$
$$L = 150.$$

Substituting and solving for S and G:

$S = 97{,}500 =$ the torsional stress in pounds per square inch

when the spring is closed coil to coil, and $G = 12{,}500{,}000$, the coefficient of elasticity. Dividing the mean diameter of the spring by the diameter of the bar gives a ratio which will be called R, in this case equal to 6.05. Dividing the permanent set by the working deflection gives another ratio, which will be called Y. In this case, $Y = .283$.

In a similar manner were calculated all the results given in the table.

Additional notation used in table :

N = number of springs in group.
O = outside diameter in inches.
H = height before closing in inches.
H' = free height in inches after producing set.
H'' = height in inches when closed solid.
$s = H - H'$ = permanent set in inches.
$x = H' - H''$ = total action in inches.

5. The value given for G in most hand books is 12,000,000. The larger values shown in the tables are doubtless due to the higher grade of steel used. The variation in values of G is probably due to differences in temper, although in some case, the chemical constituents of the steel may have varied slightly. The average value is found to be 14,700,000, which may be written 14,500,000 for convenience.

The proper stress is a more difficult thing to determine. A wide range of stresses was used in the springs experimented with. In each case the stress was that believed to be the best for the conditions under which the spring must work.

In some few cases, as in No. 18, it was necessary to use an abnormally high value to meet the conditions. This necessitated a special grade of steel, and great care in manufacture. Such a spring is not safe when subjected to sudden and heavy loads, or to rapid vibrations, as it would soon break under such treatment; if merely subjected to normal stress, it would last for years.

6. It will be noticed, by comparing columns S, Y, and R of the table, that Y varies with both S and R for the same diameter of bar; that is, if R is constant, S and Y increase together, and if S is constant, R and Y increase together. There are some exceptions to this rule noted, but it is believed to be generally correct. This being true, a spring with its mean diameter small, as compared with size of bar, will allow a higher stress

with less proportionate set than one of a larger mean diameter. An excessive set means injury to the material, and liability of failure.

Springs of a small diameter may safely be subjected to a higher stress than those of a larger diameter, the size of bar being the same. The safe variation of S with R cannot yet be stated.

There is an important limit which should be here mentioned. Springs having too small a diameter as compared with size of bar are subjected to so much internal stress in coiling as to weaken the steel. A spring, to give good service, should never have R less than 3.

The size of bar has much to do with the safe value of S; the probable explanation is this: A large bar has to be heated to a higher temperature in working it, and in high carbon steel this may cause deterioration; when tempered, the bath does not affect it so uniformly, as may be seen by examining the fracture of a large bar.

The above facts must always be taken into consideration in designing a spring, whatever the grade of steel used. A safe value of S can be determined only by one having an accurate knowledge of the physical characteristics of the steel, the proportions of the spring, and the conditions of use.

7. For a good grade of steel the following values of S have been found safe under ordinary conditions of service, the value of G being taken as 14,500,000.

For bars below $\frac{3}{8}$ inch diameter:

$$R = 3 \qquad S = 112{,}000$$
$$R = 8 \qquad S = 85{,}000$$

For bars $\frac{7}{16}$ to $\frac{3}{4}$ inch in diameter:

$$R = 3 \qquad S = 110{,}000$$
$$R = 8 \qquad S = 80{,}000$$

For bars from $\frac{13}{16}$ to $1\frac{1}{4}$ inches in diameter:

$$R = 3 \qquad S = 105{,}000$$
$$R = 8 \qquad S = 75{,}000$$

For bars over $1\frac{1}{4}$ inches in diameter a stress of more than 100,000 should not be used. Where a spring is subjected to sudden shocks a smaller value of S is necessary.

As has been noted, the springs referred to in this paper were all compression springs. Experience has shown that in close coil or extension springs the value of G is the same, but that the safe value of S is only about two-thirds that for a compression spring of the same dimensions.

TABLE.

Group.	Number of Springs.	Outside Diameter.	Mean Diameter.	Diameter of Bar.	Ratio $= \frac{D}{d}$.	Length of Bar.	Height before Closing.	Height after Closing.	Permanent Set $= H - H'$.	Height when Closed.	Total Action $= H' - H''$.	Ratio $= \frac{S}{x}$.	Load to Close Spring.	Coefficient of Torsional Elasticity.	Torsional or Shearing Stress.
	N	O	D	d	R	L	H	H'	S	H''	x	Y	P	G	S
1	15	9.25	7.9375	1.3125	6.05	150	17.25	15.25	2	8.8175	6.432	.311	10,900	12,500,000	97,500
2	20	6.625	5.375	1.25	4.3	80	7.125	7	.125	5.9375	1.062	.117	6.375	14,400,000	44,700
3	12	6	4.75	1.25	3.8	67	7.875	7.5	.375	5.875	1.625	.23	16,600	16,150,000	103,000
4	6	5.25	4.125	1.125	3.67	89	10.75	10.125	.625	7.625	2.5	.25	13,800	13,400,000	102,000
5	20	4.75	3.625	1.125	3.23	75	9.875	9.375	.5	7.25	2.125	.235	17,000	12,500,000	110,000
6	40	7.75	6.625	1.125	5.9	100	7.875	7.625	.25	5.5	2.125	.117	4,850	15,800,000	57,500
7	36	5	3.9375	1.0625	3.7	61	7.5	6.9375	.562	5.375	1.567	.33	12,000	14,400,000	100,000
8	64	5.5	4.4375	1.0625	4.18	101	11.125	10.6875	.437	7.625	3.062	.142	12,000	15,100,000	113,000
9	24	4.375	3.3125	1.0625	3.1	48	6.5	6.125	.375	5	1.125	.333	14,800	13,700,000	104,000
10	6	6	5	1	5	84	8.625	8.125	.5	5.625	2.5	.2	8,000	17,100,000	102,000
11	20	4.5	3.5	1	3.5	79	9.875	9.4375	.437	7.25	2.187	.201	12,500	14,100,000	111,800
12	16	4.25	3.25	1	3.25	49	6.5	6.125	.375	4 875	1.25	.3	13,100	13,800,000	109,000
13	36	4.75	3.75	1	3.75	37	4.5	4.125	.375	3.25	.875	.43	12,000	18,100,000	114,400
14	35	4.187	3.25	.9375	3.48	50	6.5	6	.5	4.75	1.25	.40	10,500	14,700,000	106,000
15	800	4.5	3.625	.875	4.15	57	6.375	6	.375	4.4375	1.562	.24	6,250	13,100,000	86,500
16	8	3.75	2.875	.875	3.28	41	5.375	5	.375	4.125	1.875	.43	10,800	18,100,000	118,000
17	24	4	3.125	.875	3.58	60	7.375	7	.375	5.4375	1.562	.24	8,650	13,900,000	103,000
18	40	4	3.125	.875	3.58	51	6.5	6	.5	4.625	1.375	.364	12,000	18,900,000	143,000
19	24	3.375	2.625	.75	3.5	62	7.25	7	.25	5.655	1.345	.186	5,250	13,500,000	83,500
20	8	5.75	5	.75	6.67	172	17.625	16	1.625	8.4375	7.562	.212	2,850	13,100,000	86,500
21	8	4.5	3.75	.75	5	84	8.5	8	.5	5.5	2.5	.20	4,000	15,200,000	91,000
22	12	3.5	2.75	.75	3.67	53	6.375	6	.375	4.625	1.375	.273	6,950	16,200,000	115,000
23	4	4	3.25	.75	4.33	44.5	5.75	4.6875	1.0625	3.0625	1.625	.655	6,500	15,400,000	127,000
24	24	3.5	2.875	.625	4.6	68	7.375	7	.375	4.6875	2.312	.162	3,250	13,600,000	97,500
25	100	3.25	2.625	.625	4.2	37.5	4.375	4	.375	2.8125	1.187	.316	4,225	15,500,000	116,500
26	100	3.25	2.625	.625	4.2	43	4.75	4.5625	.187	3.375	1.187	.158	4,000	16,700,000	109,500
27	200	3.5	3	.5	6	108	9.75	9.625	.125	5.8125	3.812	.032	1,250	12,900,000	76,500

DISCUSSION.

Mr. William Kent.—I want to call attention to the remarkable variation of the value of G. Paragraph 5 says, "The value given for G in most hand-books is 12,000,000. The larger values shown in the tables are doubtless due to the higher grade of steel used." I would like the words "higher grade" explained, whether that means more carbon or lower phosphorus or what other elements constitute the difference between the higher and lower grades of steel.

"The variation in values of G is probably due to differences in temper." I would like to have you show if there are experiments on record as to that. The variation of G from twelve to eighteen

millions is extraordinary, and if it is true that such a variation actually exists, we ought to know something about the causes. How can we raise or lower the value of G? The ordinary coefficients of elasticity in tension we are not able to vary at all. That is the most constant quality in steel next to its specific gravity.

Mr. Albert A. Cary.—The publication of the results of spring tests is certainly welcome to engineers, and, as Professor Benjamin has said, there are too few data available. On receiving the announcement of this paper, "Experiments on Spiral Springs," I expected to find a series of tests on springs of the clock-spring variety, but after perusal found instead that the investigation concerns compression springs, which are certainly not *spiral* springs, but *helical* springs.

This leads me to enter a formal protest against the very frequent confusion of these two terms by engineers, who certainly should not use the two names synonymously or in exchange one for the other, as is often done in referring to springs.

Kent, in his "Mechanical Engineer's Pocket Book," defines a spiral as a curve described by a point which moves along a straight line according to any given law (which line is called the radius vector), the line at the same time having a uniform, angular motion (the same as the hand of a clock). He further defines the *common* spiral as one in which the pitch is uniform—that is, the spirals are equidistant. Such a spiral is made by rolling up a belt of uniform thickness.

He further defines a helix, which (together with the definition he applies to the line traced by the threads of a screw) is a line generated by the progressive rotation of a point around an axis and equidistant from its centre.

These definitions are probably familiar to all here, but I repeat them to emphasize what I have just said concerning the confusion of the terms helical and spiral as applied to springs, which confusion I think should not be continued by the members of this Society.

The formulæ given in this paper for the calculation of helical springs are practically the same as given by Reuleaux in "Der Constructeur," and based upon the assumption that the bar or wire composing the spring is subjected wholly to a torsional strain, and the torsional stress in the bar or wire when the spring is deflected is equivalent to the moment obtained by multiplying one-half the mean diameter of the spring by the applied load in pounds.

Concerning the torsional deflection of the bar or wire: when the spring is loaded, according to this formula, we shall find that by dividing the distance the weight passes through by half the mean diameter of the spring we shall have the natural tangent of the angle of torsional deflection.

The length of the bar or wire is easily ascertained, as well as its other dimensions. With these data before us, and supposing the assumption upon which this formula is based is correct, we have merely to apply the ordinary formula for torsion as applied to straight bars or shafts to determine the strength or deflection of our spring as is done in Professor Benjamin's paper.

When interested in the manufacture of springs, a number of years ago, I made considerable use of these formulæ and found them fairly satisfactory when the diameter of the spring was large compared with the diameter of its wire, but in a majority of cases I found that my results obtained by such calculations differed more or less from those obtained in the testing scales, which led me to realize that there were many other stresses in the wire of the spring resisting the applied load, besides those of pure torsion.

When we consider the many different methods of making springs, the various ways of preparing the wire for them, their treatment during manufacture and their treatment after they leave the spring machine, we can more readily appreciate what I have just said.

We find springs made from "hard-drawn" or "hard-rolled" wire which receive no tempering treatment after being coiled.

The wire made hard by working (as just described) owes this quality (of hardness) to the many internal stresses it contains, which can be removed by proper heating and subsequent treatment; this softening process is, of course, avoided in the manufacture of springs.

Almost any of the harder metals, such as steel, iron, brass, copper, bronze, platinum, etc., can be used in the formation of such springs, which have a comparatively limited elastic limit and are easily "fatigued."

A "hard-drawn" or "hard-rolled" *steel* spring can be much improved by a process invented and patented by my father, by which the spring, after being formed and pressed, is heated to a temperature between 400 degrees Fahr. and 700 degrees Fahr., and then rapidly cooled in a blast of cold air.

A spring, after this treatment, seems to have the internal stresses

which were introduced during the coiling and pressing processes removed, its elastic limit is materially increased and it is less easily "fatigued."

In making *compression* springs by this process it is found necessary to coil them to a considerably greater pitch than is found in the finished spring, and then they must be "pressed," that is, subjected to a sudden overload (beyond their original elastic limit) which reduces their pitch considerably (although introducing new internal strains, which I will consider later) and then we will obtain a fairly efficient spring, but one inferior to a tempered steel spring.

Another very general method for making steel springs is to take wire tempered by the continuous Waterman process (which I described in Vol. XV. of the *Transactions*, page 1139) and coil it into the desired shape. The temper in the wire raises its elastic limit and makes it sufficiently hard to produce a good spring. To obtain the best results the wire must be tempered as "high" as possible to allow its being bent over the arbor or former on which the spring is shaped, and the best spring manufacturers are very particular about this point.

A compression spring made by this method will take a certain amount of "set" after it is coiled, but after being solidly compressed two or three times under an overload will not "fatigue" for a long time. Of course, internal stresses are introduced into the wire during the process of coiling, which act together with the torsional stresses when the spring is under load, but these internal stresses are practically all removed by the Cary process of tempering, described above, and a spring thus made will last almost indefinitely without fatiguing.

In the manufacture of small springs many use piano wire, which is both tempered and hard drawn, and owing to the many seemingly powerful internal stresses found in such wire, when added to the torsional stresses developed during the action of the spring, the elastic limit of the spring is soon reached by a comparatively short elongation or extension, although the resistance to extension or compression is considerably greater (within the elastic limit) than in springs formed from any other kind of wire of the same size.

This is probably due to the overstrained condition of the metal, as will be mentioned later. The stresses, due to coiling or pressing such springs, can also be removed by treating the spring finally by the Cary process of tempering.

The best and most durable springs which can be made are formed from comparatively high-carbon, soft-steel wire, which, after being finished, are " hand-tempered " ; that is, they are first heated in a charcoal fire to a cherry-red or slightly higher and then plunged into a liquid bath, which is generally of oil. They are then carefully polished (over more or less of their surface) and held above the charcoal fire until the required temper color appears, which color differs with the various qualities of steel used. There are many variations of this process, differing in small particulars, but so delicate are the different manipulations to obtain uniform results in any considerable number of these springs that the process has been almost entirely abandoned by spring manufacturers, the best of whom have adopted specially prepared tempered wire for spring stock, and after forming and machining the springs, temper them by the Cary process.

I might add here that my most uniform results in hand-tempering springs were obtained by heating and afterwards drawing them by passing an electric current through them. The wire composing such hand-tempered springs is, if they are properly made, free from all internal stresses when the spring is at rest, and, in properly proportioned compression springs, there is no setting or decrease in pitch after the coils are closed tightly one upon the other.

Another method of making springs is to take steel wire or bars and heat them to a lower temperature than a welding heat, then coil them hot on the arbor, and before they have an opportunity to cool below a dull red, throw them into an oil bath, which suddenly chills and hardens them.

The quality of steel used in this process is sufficiently low in carbon to make it unnecessary to draw the temper after hardening, but such springs are not to be classed as high grade by any means. Most of the heavy car springs are made this way.

In plunging red-hot springs into their cooling bath great care must be exercised. If they are slowly immersed sideways, often one side of the spring will be tempered harder than the other, due to the different temperatures of the opposite sides of the springs when they become immersed. A similar result is sometimes obtained when long springs are slowly immersed endwise, when one end of the spring is found harder than the other.

It is difficult for inexperienced spring temperers to produce straight springs by the " hand-tempering " process, and unless the

spring is straight axially, the distribution of the torsional stresses throughout the length of the wire will be found more or less uneven, the same as in the case of a bent shaft. In such cases, bending stresses are added to those of torsion.

I have made considerable mention thus far of compression springs, but there are equally interesting considerations in connection with springs that resist extension.

Experience has taught that the most serviceable extension springs are those coiled in such a manner as to have their coils, before extension, press closely together, and require the application of a certain initial load before the coils begin to open. This "initial set," as it is termed by spring-makers, is obtained by using hard-drawn or tempered spring wire and delivering it on to the arbor (on which the spring is formed) in a twisted manner, that is, by twisting or revolving the wire around its own axis (the same as the strands of a rope are twisted firmly together). This end is simply obtained by taking one or more turns of the wire (coming from the coil) around the handle of the tool which guides the wire upon the mandrel.

This guiding-tool either partially or completely encircles the arbor and has its handle project at right angles to the axis of the arbor, towards the coil of wire from which the spring is formed.

It has been found that the Cary process of tempering does not affect this initial torsional strain in extension springs, although the hand-tempering process, where the spring is heated to redness, destroys it.

By twisting the wire around the handle of the forming-tool in the opposite direction to that described above, the coils of the extension spring will be slightly separated. This latter method of winding is often used in forming helical springs which are to be used as torsion springs (resisting a twisting around the axis of the spring), in which case it is most desirable that the coils should not touch each other and produce friction.

I have found it difficult to predict by calculation just what the initial torsional stress in an extension spring will be, as it does not seem to be a constant quantity, and, of course, the spring will not begin to obey Hooke's law until after the coils begin to separate.

I have now mentioned some of the stresses found in the wire composing helical springs, which act together with the torsional stresses when the spring is extended or compressed, but have not

included those of bending or direct shearing which are also found in these springs, more especially in springs wound to small diameters as compared to the diameter of the wire forming them, and in compression springs having a large spacing between their coils.

When a compression spring is loaded we find (if they are free to move) the ends of such springs turning in a direction which would uncoil them, and in the case of loaded extension springs, under the same condition, their ends turn in the opposite direction, such as would tend to coil them up still further or decrease their diameter. This is partly due to a bending action, placing a transverse strain upon the wire.

Again, when a spring is sustaining a load, there exists a direct shearing strain, which tends to shear the wire across its section the same as a load on a beam tends to cause it to shear; such shearing stresses are practically negligible in springs wound many times larger in diameter than the diameter of their wire; but where a spring has a small diameter compared to the diameter of its wire this becomes a very appreciable quantity, as do also the bending stresses; and by turning to the results shown in this paper in paragraph 7, under "group 18," where the mean diameter of the spring is only about $3\frac{1}{2}$ times the diameter of the wire, I believe that the calculated results obtained by Professor Benjamin, showing a very high modulus of elasticity, were due to excessive bending and direct shearing stresses existing with those of torsion.

Concerning the matter of straining spring wire beyond its elastic limit, and the results following such "over-straining," there are some very interesting facts which do not seem to be generally understood. For instance, compression springs, when made by certain methods just described, after leaving the coiling machine, are compressed by the manufacturer under an overload which strains them beyond their elastic limit and reduces their length.

When a rod of wire is twisted beyond its elastic limit a permanent set takes place, and a point on the circumference of the wire does not return to its original position when the load is removed.

If now the twisted rod be removed, it will be found that the outer parts of the wire are subject to a negative, and the inside to a positive, strain. Next, if the bar be subjected to any twisting load less than the one which produced the permanent set, notwithstanding the fact that this new load may be greater than one which would load the spring originally beyond its limit of elas-

ticity, no further permanent set will take place, provided the wire be twisted in the *same* direction as it was twisted originally. If, however, we attempt to twist this wire in the opposite direction, just about one-half of the original load will produce permanent set. In fact, the bar in its new state has twice as much elastic strength to resist torsion in the one direction as in the other. It has two limits of elasticity for opposite kinds of twisting loads, and, if we are to avoid a new permanent set, we must take care that our twisting loads do not exceed these limits.

In tracing the many stresses found in helical springs under load, and also the varying limits of elasticity of the wire, my purpose has been to show a reason for the many expressions of dissatisfaction heard concerning the application of the formulæ given in this paper, as well as regarding other formulæ found in books treating on the subject.

During the course of my spring work, I attempted to obtain a value for G by calculations from results obtained by testing springs in the testing scale, and found in this way a very large range of variations (running from about 10,000,000 up to slightly over 16,000,000), on account of the presence of many other stresses in the wire of the loaded spring besides those of torsion.

When experience taught me to realize the reason for my unsatisfactory and variable results, I began testing torsionally straight rods of wire cut directly from spring stock, and then obtained a much greater uniformity of results, running from 12,400,000 up to 13,000,000, but averaging in the neighborhood of 12,600,000, which value I finally adopted for all kinds of steel under all degrees of temper.

I believe that this latter method for obtaining the true value of G is the only correct one.

I am sorry to find that I preserved so little data in my experimental spring work, and owing to this fact can say comparatively little concerning my determined value of S; but I find in my notes that for the maximum stress in the normal section under the load P (or, in other words, the stress at the most remote fibre of the section) for wires running larger than No. 1 gauge (which is approximately ^{5} of an inch in diameter) and for those less than half an inch in diameter, my adopted values were:

For	5-diameter	springs,	$S = 100,000$
"	10 "	"	$S = 75,000$
"	15 "	"	$S = 50,000$

The diameter of the spring used for most calculations is that measured from the centre of the wire on one side to the centre of the wire on the opposite side, at right angles to the axis of the spring. In the spring business I termed this the *pitch* diameter of the spring, to distinguish it from the inside or outside diameter.

A spring having a pitch-diameter equal to five times the diameter of the wire composing it, was commonly termed a 5-diameter spring.

It will be seen that the above values for S do not differ greatly from those given by Professor Benjamin. For smaller wires than No. 1 gauge my values for S were greater than those given above, as stated by Professor Benjamin in this paper.

I am afraid that I will be obliged to take exception to Professor Benjamin's definition of a well-proportioned spring, where he places a 3-diameter spring within the range of good proportion.

Experience has taught me that a ratio between the diameter of the wire and the diameter of the spring of 1 to 5 is as low a limit for R as it is safe to adopt for good serviceable springs. From 7 to 9-diameter springs certainly give the best all-around results, and I would advise the adoption of such proportions whenever it is possible to use them.

Mr. Geo. L. Fowler.—I am particularly interested in this paper on account of its application to railroad work, and especially as it seems to corroborate work which has already been done in that direction.

A number of years ago there was confusion upon confusion on the subject of helical springs, especially for those used as equalizer springs under passenger cars. There were any number of patents taken out on all sizes and shapes of springs—elliptic section of wire, with the major axis vertical or horizontal, diamond-shaped springs, and springs made with a taper bar—all were patented, and the railroad companies were paying very decent royalties for the use of these various fancy shapes.

Mr. Theodore M. Ely, of the Pennsylvania Railroad, came to the conclusion that his company was paying more for royalties than the thing was worth, and started an investigation in regard to a plain, round bar, coiled into a helical spring on which no patent could be secured, to see if he could not secure equally reliable and satisfactory results, using these under his passenger cars. He made a long series of experiments. I think they are given somewhat in detail in the *Transactions* of the Society, by

Mr. Cloud, Vol. V., p. 173, and the result of those experiments was a corroboration of the Reuleaux formula. That necessitated a knowledge, the gist of which is stated in the last of paragraph 6 of this paper, thus:

"A safe value of S can be determined only by one having an accurate knowledge of the physical characteristics of the steel, the proportions of the spring and the conditions of use."

That is the gist of the whole matter.

Of course, under the circumstances, a railroad has the facilities for getting all of that information. The result of the experiments made by the Pennsylvania Company was that they specified a particular grade of steel, to be handled in a particular way, in the making of a spring to be used for a particular service; on all of their work for many years past, they have worked in accordance with the Reuleaux formula, and the service has been satisfactory, and more than satisfactory in every particular. I am of the impression that the French Spring Company is doing a great deal of this work under the Pennsylvania specifications, although of that I am not positive. This paper treats of practically a repetition of previous work which has been done in the same line, and is valuable, so far as it goes, in that way; but the gist of the whole thing lies in paragraph 6.

Of course, the large railroad companies buying large quantities of springs can go into all of those matters, whereas the small buyer who uses but a comparatively small number of springs, and is obliged to specify that he wants to accomplish certain results, has to leave it entirely to the spring-maker to do the experimenting; but the spring-maker must work in accordance with this formula. My experience has shown that the Reuleaux formula is correct for all grades of material, provided you know what grade of material you are using.

*Professor Benjamin.**—I am sorry that Mr. French is not here himself to answer the questions which have been asked, and to close the discussion. I do not feel competent to answer all of these questions, as I was not present when the experiments were made and know nothing of the apparatus.

The variation in the values of G, I personally should be inclined to attribute to the combined stresses which Mr. Cary has mentioned; the formula for the modulus of elasticity does not

* Author's closure, under the Rules.

take account of these stresses, and the value of G, which is here obtained, is suitable for springs and for nothing else.

It is a good working value to use in designing other springs of a similar character, but does not in any way represent the torsional elasticity of the wire itself. The same would be true of the value of S, which is supposed to mean the shearing stress on the outer fibres. It would be correct for designing springs, but not for other purposes.

It seems to me that we are no worse off as to spiral springs, and the formulas which have been quoted, than we are in the cases of beams or columns, or in nearly every structure with which we have to deal. Each formula applies to the design of the particular kind of structure on which the experiments were made, when that formula or the constant for that formula was deduced. I note Mr. Cary's criticism concerning the use of the word "spiral." Technically he is correct, but spiral spring and spiral cutter are terms so continually used as to be understood by all.

Mr. Fowler.—I would like to ask if the springs were not all coiled hot, which would eliminate the criticism in regard to the springs coiled from a tempered wire.

Professor Benjamin.—I am quite sure that the springs were all coiled hot, and that the tempering was a subsequent process.

Mr. Fowler.—In the paper I notice it speaks of the springs being made of tempered wire. That is doubtless a mistake, then?

Professor Benjamin.—Yes, sir.

Mr. Cary.—The spring is made of a soft wire wound hot and tempered afterwards.

No. 926.*

THE HOW AND THE WHY OF THE PORRO PRISM FIELD-GLASS.†

BY WORCESTER REED WARNER, CLEVELAND, O.

(Member of the Society.)

1. SIX years ago the writer brought home from Germany a strange new kind of field-glass, called the Zeiss prism binocular, one of the first made, and among the earliest imported into this country. It looked like an eccentric and somewhat unlovely

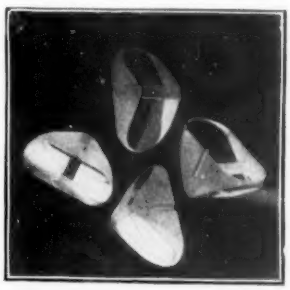

FIG. 128.—PORRO PRISMS.

opera-glass, and persons casually handling it gasped to hear that it cost forty dollars. In the meantime, however, the public has grown used to seeing prism binoculars, and hardened, in a way, to their price, realizing that they are instruments of precision, to which all other kinds of field-glasses bear about the same relation as that of a cheap watch to a fine chronometer. Each has its place in the world; the costlier is to be accounted a luxury. But what the public has not yet come to wholly understand is the reason why the prism binocular gives its mar-

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* Presented at the New York meeting (December, 1901) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For further discussion on this topic, consult *Transactions* as follows:

No. 750, vol. xix, p. 87: "The Telescope Considered Historically and Practically." W. R. Warner.

vellous results. Since these insure its permanency and development beyond all peradventure, a simple analysis of the principles involved becomes an essential part of the average man's education, and is surely not to be overlooked by the engineers forming this Society, some of whom, doubtless, own and use the instrument without fully understanding the how and the why of it.

2. The combination of prisms called by his name was invented about fifty years ago by the French engineer and optician Porro, to whom a patent was granted by Napoleon III. The principle of Porro's invention is illustrated by Fig. 129, where two prisms, each having one 90-degree angle and two 45-degree angles, are shown in their relative positions. A pencil of light, or the image of an object passing through them is inverted.

3. To follow the development of terrestrial telescopes and

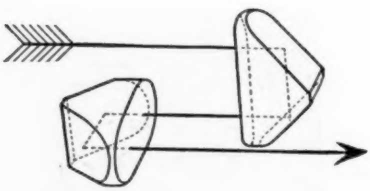

FIG. 129.—PATH OF LIGHT THROUGH PORRO PRISMS.

clearly make comparisons, we must illustrate by diagrams the principles governing the three common types of refracting telescopes, together with the Porro prism telescope.

Fig. 130 shows a sectional view of the instrument known as the Galilean telescope, which is the same thing as our common field or opera glass.

In this telescope the rays of light collected by the object-glass are allowed to pass through a system of double concave lenses *before* reaching the focus, with the result that the converging pencils of light gathered from the various parts of the field are made divergent as they emerge from the concave eye-lens ready to enter the eye. As this divergent cone of pencils of light is necessarily many times larger than the pupil of the eye, but a small part of the field gathered by the objective can be utilized; hence the very small field of view in all telescopes of this type. This limitation necessitates very low magnifying powers, the highest we find being but 6 diameters, while the

usual power for Galilean field-glasses is but 4 or 5 diameters, and for opera-glasses but 2 to 3 diameters, which latter is generally considered sufficient for ordinary theatre use.

4. Fig. 131 illustrates the arrangement of lenses and the path of light-rays in the type of terrestrial telescope commonly known as the "spy-glass."

The rays of light gathered by the object-glass reach their focus at the "focal plane," and back of this is the system of

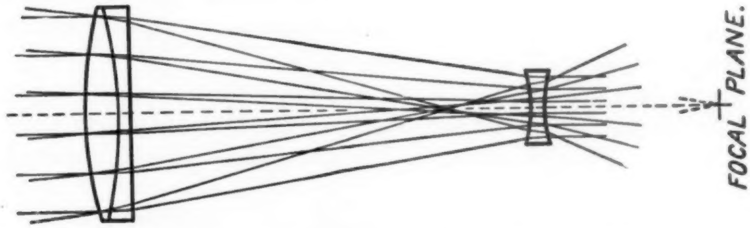

FIG. 130.—GALILEAN TELESCOPE (OPERA-GLASS).

lenses forming the erecting eye-piece, from the eye-lens of which the pencil of light passes to the eye. In this type, also, the field of view is necessarily so reduced as to make the use of the instrument very unsatisfactory. It must be quite long, too, and therefore very hard to hold steadily.

5. Our next illustration is the astronomical telescope shown in Fig. 132.

This is the most simple and most perfect of all. As in the other types, the object-glass gathers the light and sends it down

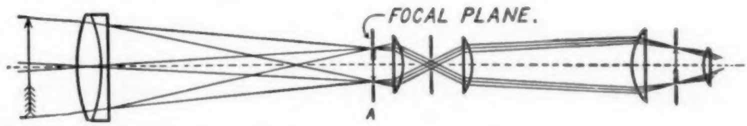

FIG. 131.—TERRESTRIAL TELESCOPE (SPY-GLASS).

toward the focus at the "focal plane," where it is taken by the simple astronomical eye-piece. Thence it emerges in a pencil of light smaller than the pupil of the eye, which, by using the same magnifying power as in the other types mentioned, is enabled to observe a field of view three times the diameter (nine times the area) shown in either of the instruments illustrated in Figs. 130 and 131. But in this instance the object is seen inverted.

All astronomical telescopes show the object thus; which is all right for the stars, but will never do for terrestrial observation.

6. Now, if we could erect the image of the object shown in the astronomical telescope, we should have the finest terrestrial telescope possible. This is just what is done by introducing the Porro prisms. The object is now shown with all the clearness, definition, and large field of the astronomical telescope, and in an erect position; and so the pretty problem is solved.

7. But there are several questions to be asked by the thoughtful man who handles one of these field-glasses. We may as well anticipate them, and answer them in turn.

First. Just how do the prisms do their part?

The prisms serve a twofold purpose, the first and most important being, as has been said, the erection of the object observed,

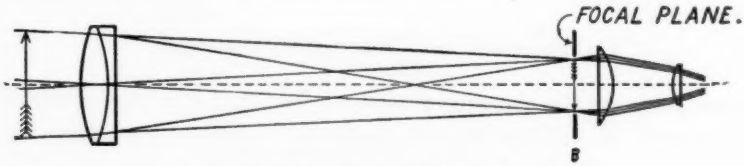

FIG. 132.—ASTRONOMICAL TELESCOPE.

and the second, the shortening of the telescope by twice turning the ray of light upon itself, so that the total length adjusted for use, whether for 6, 8, or 10 power, is but four inches, and the total weight, in binocular form, but thirteen ounces, so small and light, indeed, that it can easily be carried in the pocket.

Each triple barrel of the prism field-glass contains two double reflecting prisms, as shown in the diagram, Fig. 133.

The rays of light passing through the object-glass enter the first prism in such a way as to be twice totally reflected, each time at an angle of 90 degrees, thus emerging parallel to the entering ray, but in the opposite direction. It is then caught by the second prism, and is similarly reflected and sent on its course toward the eye-piece, in its original direction, without change, except in one very important particular; viz., the image of the object observed, which without the intervention of the prisms would be upside down, is now erect, and is ready to be magnified by the simple astronomical eye-piece, just as the stars and planets are magnified in the largest telescopes.

Second. How can the field be so surprisingly large here, or

why is the field shown by the old-time glasses so small? Let us try and get a correct comparison of the two types of telescope.

8. When observing with the Galilean telescope (opera-glass type), the axes of the pencils of light flowing from the several parts of the field gathered by the objective are divergent as they

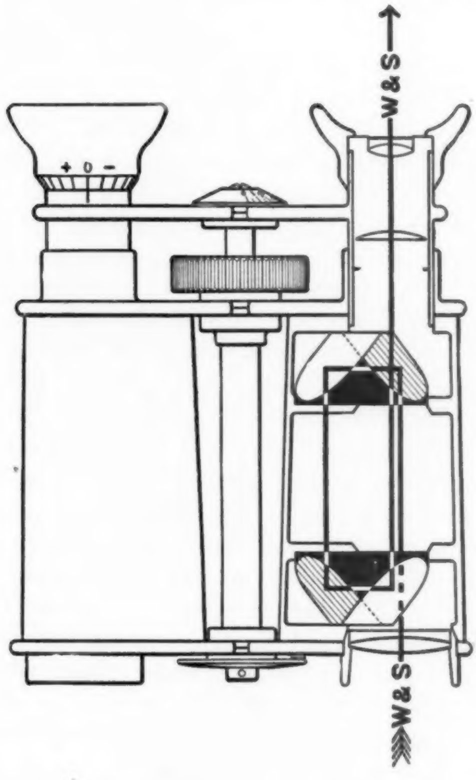

FIG. 133.—WARNER & SWASEY UNIVERSAL PRISM FIELD-GLASS (SECTIONAL VIEW).

emerge from the concave eye-lens; and as they cover an area many times the size of the pupil of the eye, most of the light is lost; the field utilized is very small, and can be moved over an extended area by moving the eye about the eye-lens of the instrument, as when looking through a paper cone from the *larger* end.

The Porro prism field-glass is constructed on exactly the

opposite principle. The axes of the pencils of light coming from the several parts of the field are concentrated by the convex lenses of the eye-piece, and emerge from the eye-lens in a pencil of light small enough to all enter the pupil of the eye, in the same natural manner as we observe with the unaided eye in looking through a paper cone from the *smaller* end, without strain or weariness to the eye, thus giving a large and uninterrupted field of view, three times the diameter (nine times the area) possible in the old style instrument of the same power, as shown by Figs. 134 and 135.

9. In the development of the prism binocular it has been found that the magnifying powers which may be most advantageously used range from 6 to 10 diameters. It is true that no one power is best for all purposes. A good average, however, is reached in the 6 and the 8 powers, which are those in most popular use. The uninitiated often make the mistake of thinking that the highest powers are most desirable, which is far from the fact. Any increase in power must be met by a decrease in field of view, by a diminution of light, and also by an increase in the effect of unsteadiness of the instrument while observing. The Porro prism glasses are so short that they can be better held than any other kind of terrestrial telescope, and therefore there is no practical difficulty in holding an 8-power with sufficient steadiness to make terrestrial observation successful. Any higher power than this is apt to cause annoyance from the reasons mentioned, while the 6-power (which is as high as any of the old-style Galilean field-glasses) is eminently satisfactory for natural history and general landscape observations, and the fact that its field is three times as large as is possible in the Galilean telescope of the same power is enormously in its favor.

10. A few minutes' practice will enable one to quickly determine the power of any opera or field glass.

Place the left eye-piece to the right eye, closing the left eye meanwhile, and carefully focus on a near object, preferably a window across the street. With this object clearly in view, open the left eye, when two images of the window will be evident —one magnified by the instrument and the other as seen by the unaided left eye. An instant's comparison will show how many times longer and wider is the image shown by the telescope than the one viewed by the unaided eye. This ratio represents the power of the field-glass in diameters.

The magnifying power of the two field-glasses can readily be compared by observing an object with both at the same time, using one eye for each of the glasses tested.

FIG. 134.—FIELD SHOWN BY THE BEST PRISM FIELD-GLASS.

11. The many special advantages possessed by the Porro prism field-glass early attracted the attention of Government

FIG. 135.—FIELD SHOWN BY THE BEST OLD-STYLE FIELD-GLASS OF THE SAME POWER.

officials throughout the world, and after searching investigation and severe tests these instruments have been very generally adopted for Government use. During the last year Germany

ordered over six thousand of them, while England has sent as many or more to South Africa; and in the various departments of our own Government they have become very popular and are rapidly taking the place of all other field glasses. The fact that they give greater power and field, with better definition, and at the same time are but a fraction of the size of the old Galilean type, is a sufficient explanation of their popularity for Army and Navy use.

12. In view of the great advantages possessed by these instruments over all other terrestrial telescopes, why, you will ask, did the invention wait a half century before practical use was made of it? There are at least two adequate reasons:

First—The best optical glass manufactured at that time absorbed so much light as to render impracticable the successful use of Porro prisms made of it.

Second—Opticians have only within recent years known how to make absolutely flat surfaces, without which the object seen through the Porro prism telescope is distorted.

Both difficulties have been brilliantly conquered. The borosilicate glass made by Mantois of Paris and Schott of Jena, and which is exclusively used for these prisms, is so nearly perfect that but 4 per cent. of light passing through it is lost by absorption. Moreover, optically flat surfaces are now made correct within a limit of less than one-tenth of a wave-length of light (meaning, in linear measure, less than $\frac{1}{500,000}$ of an inch), and it is a proper source of pride to us all that our own honored fellow-member of this Society, Mr. John A. Brashear, is the founder and head of the works which lead the world in this class of production. The spectroscope prisms made in his laboratory are in use in the leading observatories of the world and have never been equalled, while the Porro prisms, which he manufactures by the thousands, are the most perfect ever made.

13. The credit for first applying the principle practically in bringing out a successful Porro prism field-glass belongs to Dr. Abbe of Jena, the able leader and manager of the famous Zeiss works, which have done so much in perfecting optical instruments. This was in 1895. Dr. Abbe's instrument, known as the "Zeiss," is shown in Fig. 136. This represents the original design which has remained unchanged since its introduction in the year mentioned. The focal adjustment is made by separately turning each eye-piece on its axis. The American makers of

this instrument, the Bausch & Lomb Optical Co., have recently improved it by adopting a universal focal adjustment. The two triple tubes are hinged so as to allow adjustment between the eye-pieces to suit the pupillary distance of the eyes of the observer. The hinge so connects the tubes as to place the objectives about an inch wider apart than the eyes, which feature has been alleged to impart a stereoscopic effect. As a matter of fact, the clearness and the sharpness of definition in these instruments were so far in advance of what had been previously obtained that the improvement was mistakenly attributed to the greater

FIG. 136.—ZEISS PRISM FIELD-GLASS.

width between the objectives. This belief is still held by some persons who have not investigated the claim.

14. The facts are, however, easily demonstrated by means of an instrument invented for the purpose and shown in Fig. 137. In the barrels of this instrument the triple telescope tubes are mounted to swing on the optical axes of the eye-pieces in such wise as to admit of being turned either to give the objectives the same relative position as shown in the Zeiss instrument, or to a position practically the same distance apart as the eyes. As the cut shows, the instrument is so constructed that tests can be made without the observer's knowing the positions of the objec-

tives. Thereby all prejudice is eliminated, with the result that the keenest expert, observing an object across the street, or the distant landscape, cannot tell in which relative position the objectives are placed; which fact conclusively proves that, for field-glasses the claim of increased stereoscopic effect by an increased separation of the objectives is untenable.

15. A short time after the introduction of the Zeiss glass came the Goerz binocular, illustrated in Fig. 138. This is also made in Germany. The pupillary distance is adjusted by parallel slides actuated by racks and pinions. A similar movement also gives universal focal adjustment. The present design of this

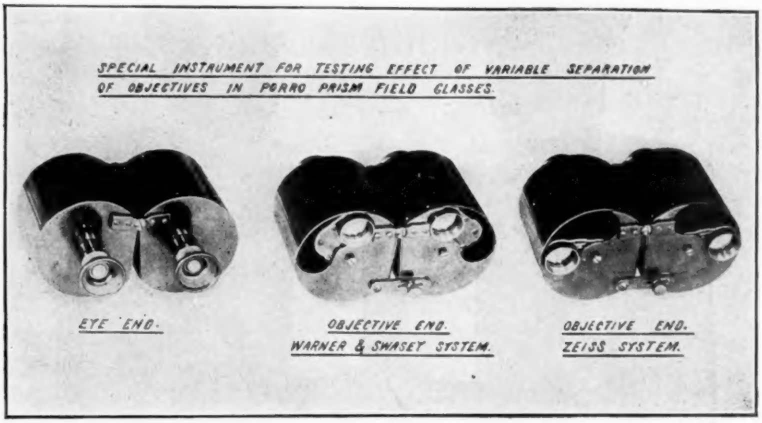

FIG. 137.

instrument is the same as when first put on the market five or six years ago.

Fig. 139 shows the American model of universal prism field-glasses, brought out by The Warner & Swasey Company two years ago. The illustration is largely self-explanatory and shows how simple and symmetrical design may embody all essentials with a minimum number of parts. That this point is appreciated is proved by the fact that the design has been frankly copied by leading manufacturers in this country and in England.

As an evidence of the development of manufacturing in the United States, it may be added that the highest quality of Porro prism field-glasses are made here and sold at the same prices that are charged for similar instruments in London, Paris, and

FIG. 138.—GOERZ PRISM FIELD-GLASS.

Berlin, the American interchangeable system of manufacturing counteracting the effect of European cheap labor.

So, then, for soldier and sailor, sportsman and scientist, tour-

FIG. 139.—WARNER & SWASEY UNIVERSAL PRISM FIELD-GLASS.

The American model.

ist and—engineer, let us say—these admirable instruments are being turned out in ever increasing numbers, and there is no limit yet apparent to the demand ; for, be it remembered, in our progressive country, the luxuries of to-day are the necessities of to-morrow.

DISCUSSION.

Mr. William Kent.—I would like to ask Mr. Warner to explain how it is that the rays which enter the prism get deflected at right angles, while the parallel rays the second time around go through and are not deflected.

Mr. Warner.—You are referring to Fig. 133? Please refer to Fig. 129; that will answer the question. The two Porro prisms are set so that the long axes of the prisms are at right angles with each other.

Mr. Emory.—I do not rise in criticism of the paper, but to ask for information upon one or two points. Mrs. Emory has been using the glass for observing birds—studying birds in their native haunts. In order to study the bird properly it must be studied through the glass. She soon concluded that either she was a very poor observer or the standard books on ornithology were wrong, because she could not get the tints to agree

In studying nature the question is as to truthfulness of color. She observed that the finer tints of some of the birds, where the tint is delicate, is difficult of distinction, but the definition is very much finer than with the other glasses ; you can see a bird much quicker ; you can get it in focus quicker ; and you can catch it on the wing—in fact, make very much finer observations of the form, flight, and other characteristics of the bird.

I suppose that the manufacturers have considered this matter very carefully and know to what extent this difficulty has been eliminated. I would like to know to what extent it can be further eliminated.

Mr. Warner.—I am very glad to say, just at this point, that Mr. Brashear has come into the room ; he has made a scientific study of color—in fact, has delivered lectures on the subject and given all of these details—and if Mr. Brashear will answer Professor Emory's question it will be much more satisfactory to all, I am sure.

Mr. John A. Brashear.—The question is certainly a legitimate one. The selective absorption in glass is a question which is very interesting to the optician. Some of the finest and most

valuable kinds of glass have recently been invented by the manufacturers of optical glass in Jena in Germany, the government having provided a subsidy of some 60,000 marks for experimental purposes.

The glass from which the prisms of this binocular is made is one of the new kinds made at Jena, and is called boro-silicate crown; as Mr. Warner has already pointed out, it is very superior for this purpose, having but a small selective absorption for the white light which passes through it.

This is not the case with a great many reflecting and refracting materials. Take, for instance, a highly polished silvered surface such as we find in the best mirrors. You would probably imagine that it reflects most of the light which falls upon it; but if you arrange two mirrors in such a way that a beam of white light, containing all the colors of the spectrum, shall have twelve reflections, you will find the beam of light at the last reflection to be almost pure red, having been robbed of the violet, blue, and green waves. Many kinds of glass have the same properties. The dense Faraday glass will absorb nearly all the short waves after transmission through four or five inches of thickness.

The boro-silicate crown is very white and transparent. It is also what we call a *dry* glass. Many of the crown glasses made have a great affinity for the moisture in the atmosphere, perhaps on account of the potash in them, and are called hygroscopic. They soon become dimmed over the surface, thus shutting out, as well as diffusing, much light. The polished surface of the boro-silicate crown remains free from "patina" for years.

I wish to say that the larger share in the development of this excellent field glass is due to The Warner & Swasey Company. They have studied it in every part, eliminating all superfluous attachments; made every part interchangeable; and, what is most important, have given to the two systems (*i. e.* the two tubes, with their optical parts) a most perfect alignment with one another, without which, even if all other things were made perfect, the instrument would not fulfil the function of a high-grade field glass.

I have been requested so many times by our secretary and other members of the Society to give you a paper on the preparation and testing of accurate optical surfaces that I will bend every effort to prepare such a paper for one of our meetings in 1902.

Mr. James M. Dodge.—I would like to ask Mr. Brashear whether the tremulousness of the glass when held in the hand does not account for a great deal of the difficulty. I know by personal experience in using marine glasses on a power yacht, that the vibration of the engine makes it very difficult to distinguish clearly the red and green lights of other vessels. There must be an impression made on the eye by the motion that is confusing. If the glass can be held with absolute steadiness, it is possible to distinguish objects which can not be seen if the glass is shaking.

Mr. Brashear.—That is true in one sense of the word, and also in another, in that the powers being so high add to that tremulousness, because it must be remembered that every increase of power put upon an instrument magnifies all motions and imperfections in the same ratio, especially disturbances in the atmosphere.

*Mr. Warner.**—Just a word regarding the power, the question raised by Mr. Dodge. It is most natural, and, I think, usual, for people purchasing a terrestrial telescope, especially of the binocular type, to feel that they want to get as high a power as possible.

I remember meeting a gentleman on the steamer who had a field glass magnifying twenty diameters which I think cost eighty dollars, or about that. While he was observing a passing ship—and, as he had this fine glass which he had bought in Paris, many of his friends were around him, also watching the ship—I stepped up to him and asked the privilege of trying it, and incidentally I said, "Can you read the name of the ship?" He said, "No, I cannot." I handed him an eight-power prism glass to use while I was using his, and he at once read the name with the low-power glass; not because the low power would define it better if it was still, but because, with the high power, the motion of the steamer and the tremulous motion of his hands made it very difficult to define anything; while the lower power, having a lesser apparent motion, enabled him to at once read the name of the ship.

Mr. Brashear.—There is an axiom among astronomers which may be of value to you gentlemen who have to use telescopes occasionally. The axiom is: always use the lowest power with which you can see best the object observed.

* Author's closure under the Rules.

No. 927.*

A PORTABLE ACCELEROMETER FOR RAILWAY TESTING.

BY F. B. COREY, SCHENECTADY, N. Y.
(Member of the Society.)

1. THE recent rapid development of high-speed transportation, especially that which involves the use of electricity as the motive power, is largely due to the attention given by railway engineers to the most minute details of locomotive and train performance. In order to obtain exact information concerning these details, most exhaustive tests are instituted, and for the proper carrying out of these tests new measuring instruments have been devised, both for indicating and recording the magnitude of the various functions involved. In all railway work, both steam and electric, the all-important factor to be considered is speed, and it is often necessary to secure accurate data in regard to the rate at which the speed changes under various conditions of equipment and operation. To obtain the desired information from a continuous speed record is generally as unsatisfactory as it is laborious, and various devices have from time to time been tried in order to secure direct readings of acceleration and retardation of moving cars and trains.

2. The following seem to be the requirements to be met by a practical instrument of this class:

(*a*) It should have no delicate moving parts.

(*b*) It should be susceptible of accurate calibration, and this calibration should be permanent.

(*c*) The reading scale should be sufficiently extended to render the readings reasonably accurate.

(*d*) It should be practically "dead-beat" to record rapid fluctuations.

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* Presented at the New York meeting (December, 1901) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

(*e*) It should not require for its operation any mechanical connection with the axle.

(*f*) It should be of such size that it may be readily carried about in small space.

(*g*) It should either be independent of grades or be capable of measuring the degree of inclination, so that its indications may be readily corrected.

In addition to the above requirements, it is extremely desirable that the instrument be such that continuous records may be made, so that we may properly study the various changes of acceleration and retardation throughout any given period of time.

3. The instrument which I am about to describe seems to satisfy, in greater or less degree, each of the above requirements, and, although it has certain limitations, I believe it to be more generally satisfactory under the various conditions of practical testing than any instrument of the kind heretofore used.

The action of this instrument depends upon the inertia of a small mass of mercury contained in a horizontal passage, the ends of which are in communication with two short vertical columns of mercury. Thus, the flow induced in the horizontal passage produces a difference of level in the vertical columns, which difference of level is wholly dependent on the horizontal component of the acceleration in the plane which passes through the axes of the two vertical columns. Upon this difference of level, or rather, upon the change of level of either column from a given zero position, must depend the indication of the instrument. In a small instrument, however, such as might be conveniently carried in the pocket, this change of level is very small. For instance, assuming a distance of four inches between the centres of the mercury columns, the change of level would be less than three-eighths of an inch for an acceleration of four miles per hour per second, which is about the maximum possible on steel rails. It is therefore evident that some method of multiplication must be used to secure a reading scale sufficiently extended for practical work. For this purpose, colored alcohol or other liquid of low specific gravity is introduced into the spaces above the mercury columns, to which spaces the reading tubes are connected. The reading tubes are of comparatively small diameter. Thus, the ratio of the cross-section

of the mercury column to the cross-section of the reading tube becomes approximately the multiplier of the changes of mercury levels. The upper ends of the two reading tubes are connected together so as to prevent evaporation and spilling of the liquids. The reading scale is provided with vertical adjustment to facilitate the proper location of the zero point.

Fig. 140 is a photograph of the instrument as arranged to be carried in the pocket. In this form it is found to be very convenient. By placing it on a window ledge, or other convenient

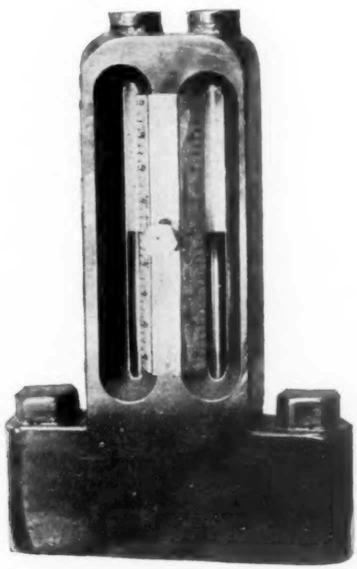

FIG. 140.—POCKET ACCELEROMETER.

place, the acceleration and retardation of any car may be easily observed.

Fig. 141 is a partial section, showing its construction. This particular instrument is made from hard rubber with glass reading tubes sealed in.

4. Since the acceleration of gravity (32.2 feet per second per second, or 21.95 miles per hour per second) is produced by an accelerating force (resultant) of unity, that is, of 2,000 pounds per ton, it is evident that acceleration may often be best expressed in effective pounds accelerating force per ton weight of car or train. Hence we have two separate scales for reading in

either unit desired, each of which units is readily convertible into the other.

If we represent any given horizontal acceleration as a fractional part of the acceleration of gravity, as $g \div n$, the angle which the surface of any liquid thus accelerated will make with the horizontal is that whose tangent is $1 \div n$. Therefore, in the calibration of this instrument, we have only to lay out a series of angles whose tangents are, say, .05, .10, .15, and .20, and place the instrument at the corresponding inclinations to determine the points on the reading scale corresponding to the effective

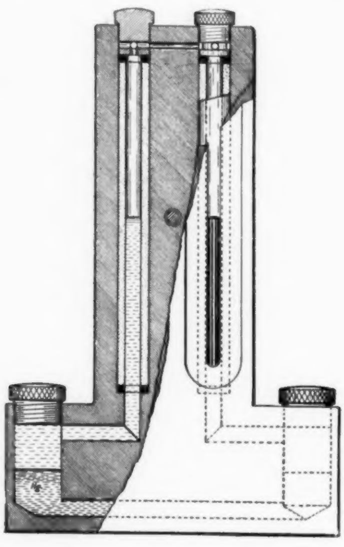

FIG. 141.—SECTION OF ACCELEROMETER.

accelerating forces of 100, 200, 300, and 400 pounds per ton respectively.

5. It is evident that if the accelerometer be set to the zero position when the car is either at rest or moving uniformly on either a level or gradient, the indications will be accurate only so long as the car remains on track of constant grade. When the grade changes, the accelerometer must be readjusted or the proper correction made. Usually either a stop or a period of constant speed running gives opportunity to reset the instrument or determine the correction. When this cannot be done at the time of testing, the accelerometer should be set at zero

on a level track, and the car run over the road and brought to rest on all grades to be measured. It is evident that used in this way the instrument becomes a gradiometer, giving an indication of twenty pounds per ton for every one per cent. of grade.

6. I referred above to the desirability of an accelerometer by which continuous records could be made. In fact, without some such device, the accelerometer is useful only in measuring maximum and minimum values. Fig. 142 shows the instrument

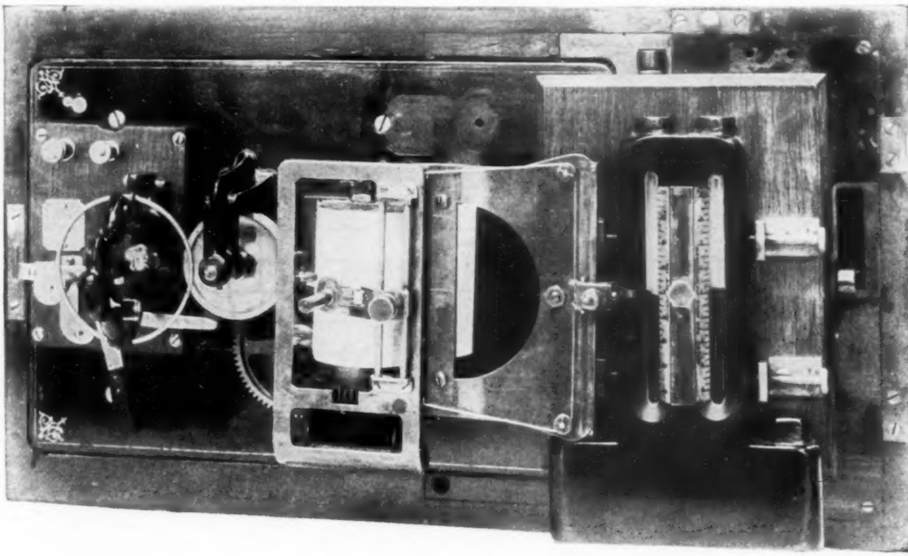

FIG. 142.—RECORDING ACCELEROMETER.

described above, mounted on a recording device that is a modification of one originally used in connection with an ammeter. In this device the fluctuations of the instrument are followed by hand, the record being produced upon a continuous strip of coated paper which is caused to pass at uniform speed over a drum; the drum was driven by an ordinary phonograph motor. This method of producing record curves has been found to be entirely satisfactory.

7. Fig. 143 is a reproduction of a portion of the record strip of a run with a single car of approximately 40 tons weight, equipped with standard electric train-control apparatus, the part shown representing a short run (between stations) from start to stop.

On the vertical scale 1 space represents 50 pounds per ton effective accelerating force, or .55 mile per hour per second acceleration, while on the horizontal scale 1 space represents a time period of 10 seconds.

The interpretation of this diagram is as follows: Beginning at *A*, the acceleration rises very rapidly, indicating 1.4 miles per hour per second after an elapsed time of 1.5 seconds. The acceleration rapidly falls off until the master controller is turned to the second notch, when it again rises, the maxima and minima depending largely upon the skill or wishes of the motorman. At *C* is seen an almost instantaneous drop in acceleration,

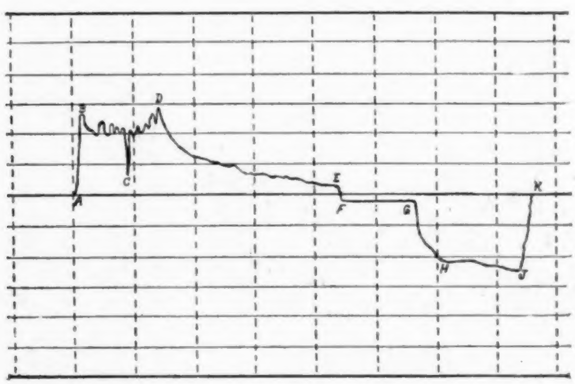

FIG. 143.—RECORD FROM ACCELEROMETER.

the curve theoretically touching the base line. This occurs at the point of transition from the series to the parallel motor combination. The error here is due more to inability to follow accurately the sudden fluctuations than to any fault in the operation of the instrument itself. At *D* the full parallel position is reached, when the acceleration rapidly falls off until, at *E*, it has dropped to about .14 mile per hour per second. At this point power was cut off and the acceleration immediately dropped to a negative value of about .13 mile per hour per second, equivalent to a retarding force of about 12 pounds per ton due to friction. The distance *FG* represents the time during which the car was allowed to coast freely. At *G* a service application of the air brakes was made, the retardation rapidly increasing until, at *H*, the full power of the brakes is applied. From *H* to *J* the gradual increase in retardation will be noted, due to the

increase in the coefficient of friction with reduction of speed. At *J*, just before the car came to a full stop, and when the retarding force had reached a maximum of 125 pounds per ton, the brakes were partially released and the car was brought easily to rest.

8. There is, of course, an error in this instrument due to the difference in the ascending and descending meniscus surfaces. With columns of as large diameter as those used, however, this error would, under any circumstances, be small, and here it is almost entirely obviated by the slight but rapid vertical vibration of the moving car.

One of the most noticeable characteristics of this instrument is the accuracy with which it will follow rapid changes without excessive, and sometimes without perceptible, oscillation due to the inertia of the moving liquids. The best results are obtained when the cross-section of the passage at the bottom of the mercury columns is so proportioned as to give the proper damping effect.

9. If any given acceleration be multiplied by the time during which it is maintained, the product is the resulting increment of speed. It is therefore evident that the integrated area between the acceleration curve and the datum line up to any given ordinate multiplied by a proper constant is the speed of the car at the corresponding instant. This constant, or the speed per unit of area, is equal to the scale of abscissas multiplied by the scale of ordinates. For example, in Fig. 143 the area included between the acceleration curve and the datum line up to the instant at which power was turned off is found to be 0.66 square inch. Therefore the speed of this car at the instant corresponding to *E* on the curve was 20 (seconds) multiplied by 2.2 (miles per hour per second) multiplied by 0.66 = 29 miles per hour.* If the speed is to be measured at any instant during retardation, the required area is the algebraic sum of the areas above and below the datum line up to the designated ordinate. Thus, by means of the planimeter, the instantaneous speed of the car may be measured directly from the accelerometer record.

10. Another useful application of the accelerometer is in the measurement of running friction under different conditions of operation. The accelerometer, as has been explained, gives

* On the original diagram, 1 inch on the vertical scale equalled 2.2 miles per hour per second acceleration and 1 inch on the horizontal scale, 20 seconds.

directly the effective resultant accelerating force per unit of weight. If, therefore, we know the mass moved and the force applied at the axle or draw bar, we readily obtain the friction loss at any instant by comparison of this force with the indication of the accelerometer.

From the above, it will be seen that an instrument of the class described, although not strictly an instrument of precision, is of great practical value to the railway engineer, and it is to be hoped that improvements may be made in the near future that will still further enhance its value as a testing instrument.

DISCUSSION.

The Secretary.—There has been received from Mr. Don. J. Whittemore, member of the Society, a letter calling attention to a paper read by himself before the Western Society of Engineers on September 7, 1898, in which he calls attention to the fact that he presented and described at that time an instrument having many of the same features which have been elaborated by Mr. Corey. He encloses a photograph of the instrument, which appears to be almost similar in form to the original of Fig. 141 in the paper, and which was discarded by reason of errors in determining acceleration, retardation, or centrifugal forces. Mr. Whittemore's apparatus was designated an "Equilibristat." It is Mr. Whittemore's opinion that the source of the error arises when the instrument is calibrated by gravity alone, by inclining the device, and would be greater in proportion to the combined length of the horizontal tube containing alcohol as compared with the combined length of the tube containing mercury. If the alcohol tube be 3 inches and the mercury tube 4 inches, the error would be approximately—

$$\frac{\text{Specific Gravity of Alcohol} \times 3}{\text{Specific Gravity of Mercury} \times 4} = \tfrac{1}{22} \text{ nearly.}$$

Mr. Wilfred Lewis.—I may say that four or five years ago I had occasion to devise an instrument for a similar purpose, which I described in a paper read before the Engineers' Club of Philadelphia as an inertia indicator. The instrument was not without defects, and it could not be called an instrument of precision ; and I was rather disappointed to find that the instrument under consideration had not advanced to be entitled to that distinction. The recording apparatus is apparently not automatic ; the move-

ment of the column must be followed by the eye, and a record must be made by hand. The same, of course, can be done with the instrument which I described at that time, and which is shown here [exhibiting the instrument].

It is simply a curved tube, like a spirit level, almost filled with alcohol, leaving an air bubble to be laid in the direction of acceleration, and it is graduated into tangents of the angle of curvature so as to register the percentage of acceleration in terms of the load moved. If in a trolley car it is laid on the window-sill, it shows about 12 per cent. in the starting and stopping; on railway trains, about three per cent. in starting and about 12 per cent. in stopping. The instrument under consideration, I imagine, would do the same, but they are both subject to lag. An instrument of this kind to be accurate must be instantaneous, and it is impossible for it to be instantaneous if any weight is involved. In this case the weight involved consists of a horizontal column of mercury and the fluid which is carried on top. To prevent overrun it is necessary to choke the flow, and if the time limit is short, it will not reach the figure which it should. I do not know which of the two instruments would be preferable. They might be tested together. The mercurial accelerometer has the possible advantage of using a rider to indicate the limit of motion, whereas a similar index is not conceivable in an instrument of this kind, where readings are taken from the position of an air bubble. But in the case of a column it would be possible, I have no doubt, to make use of a rider similar to that used in maximum and minimum thermometers. Very often the movement is so quick that you cannot follow it with the eye; the bubble runs to a certain point, and drops back before you have time to read it; but where the acceleration is continued for a sufficient length of time, the indications, I think, are very good.

I had occasion to use it in measuring the inertia of travelling-crane bridges, where the effect of the movement was an important matter in determining the strength required for the building. It served that purpose very well, because the time of acceleration was sufficiently long to allow the bubble to make its movement and stay there to be read. Want of time to move and be read is the difficulty in an instrument of this kind, and I think there is quite a field for an accelerometer which will be an instrument of precision, and which will be self-recording, which this is not as yet.

Mr. Geo. L. Fowler.—I have had occasion within the last two

or three years to make a number of experiments on railway trains and cars hauled by almost every conceivable method of propulsion, and to measure the acceleration at very short intervals. I have tried various devices, but found that anything which depended upon the reading of the eye was altogether too unreliable.

In the first place, you cannot read rapidly enough and make your records. You cannot read with short enough intervals of time, and there is such an amount of vibration, and so much variation in the acceleration at very short intervals, that the records are unreliable unless they are made strictly automatic.

The most satisfactory apparatus which I have ever used consists of two very simple little contrivances. One is an ordinary double-registering telegraph instrument, the other a clock which will make and break a circuit on quarter or half second intervals, with a contact device placed on the axle of the car, which will make and break the circuit either on half or whole revolutions, depending upon the diameter of the wheel. By running one circuit from the contact on the axle through one pen of the recording device, and the other circuit from the clock through the other pen, I obtained two records of simply a series of dots, one series representing the circumference of the wheel or the semi-circumference of the wheel, according to the contacts, and the other representing quarter or half second intervals. By running the paper with sufficient rapidity it is a very simple matter, with an ordinary pair of dividers, to get your time intervals down to a twentieth of a second; that is well within the range of an ordinary scale. In that way the plotting of the acceleration curve becomes a simple matter which can be put in the hands of any draughtsman. It does away entirely with the personal equation of the observer and leaves a record that is positive in every particular and thoroughly reliable. But an instrument which depends upon a record that a man has to take and set down, diverting his eye from the instrument to his paper, or even having an assistant to make his record, is, for accurate and close work on the acceleration of a railway train, in my opinion, absolutely and totally unreliable.

Mr. John A. Brashear.—It may be interesting to know that Professor Langley used such a device as the gentleman has just spoken of in his aërodromic studies. He called it a dynamometer chronograph, and by it was enabled to record automatically the energy necessary to raise the body of a bird when the same was set with wings at various angles, as also to register the energy

given out by certain propellers which were devised to attach to various forms of flying machines. These papers have been published by the Allegheny Observatory and the Smithsonian Institution, and would no doubt be of value in the hands of such a competent observer as Mr. Corey.

Mr. A. A. Cary.—How would you attach it to flying birds?

Mr. Brashear.—The birds in question were not living specimens; but were carefully prepared, with wings spread in as natural a position as could be given. Such birds as condors were secured, with wings set at various angles on an almost frictionless slide, so that when the rotating arm attained sufficient speed the bird would rise between the slides, and the motion transmitted through proper means was at once registered upon the barrel of the chronograph.

Prof. Albert Kingsbury.—Several speakers have referred to the undesirable feature of this instrument involved in the registration by hand, or following by hand the indications of the instrument in order to produce one of the elements of the graphic record. The feature is one which I found valuable for certain kinds of tests. Perhaps for this particular instrument, where the variations may be rather rapid, and therefore difficult to follow accurately, it may not be so useful; but I have found this kind of recording apparatus quite useful in drawing stress-strain diagrams for tests of materials. In this case the indications of the extensometer or equivalent device do not vary very rapidly, and the observer can follow them accurately by hand while the load or stress is recorded mechanically.

I wish to call attention to another point, however; viz., that of the corrections for grade. The author indicates three methods of allowing for grades : (*a*) stops, or (*b*) periods of constant speed, either of these giving opportunity to reset the instrument; (*c*) bringing the car to rest on all grades to be run over. Of these methods (*a*) appears to be out of the question in ordinary running; (*b*) might be satisfactory if there were means of determining when the speed is constant; but if the accelerometer is to be the means for determining constant speed, it should be remembered that even if it indicated zero acceleration, this might be due to an unknown grade and an acceleration having an effect on the instrument opposite to that of the grade. The method (*c*) would require some means for identifying the position of the car on the track at any instant when the run is made, a requirement for

which no provision is suggested. It would therefore seem that the usefulness of the instrument must be limited to runs on a level track or on long, uniform grades, unless the grades be so slight as to be negligible.

Mr. A. A. Cary.—Mr. Fowler spoke of the use of a chronographic arrangement in his apparatus. I have, in my work, used a chronograph having a second's pendulum closing its periodic electric circuit by dipping the extreme lower end of the pendulum in a small cup of mercury placed directly below its point of suspension.

I do not see how a pendulum chronograph could be used on a train which is constantly being accelerated or retarded. Such changes in its condition of motion must necessarily affect the vibration of the pendulum and cause it to "lag," or else be accelerated, and thus destroy its function as an accurate timekeeper.

On the other hand, should a balance-wheel clock arrangement be used, having an electrical contact piece placed on the balance-wheel to close an electric circuit periodically, such an arrangement would throw the whole clock out of balance and thus destroy the accuracy of any record it might make.

These are difficulties which suggest themselves to me, and probably Mr. Fowler has encountered them and found means to overcome them; if so, I would like to hear how he has accomplished such satisfactory results.

Mr. Fowler.—Yes, we encountered them. In the first place, we did not use the pendulum clock. I must say that my clock arrangement is due originally to Mr. Park, of the Westinghouse Air Brake Company. He took an ordinary Seth Thomas clock, and after a great deal of labor, a great deal of trouble, and a great deal of expense, succeeded, with the assistance of a very skilled clockmaker and electrician, in getting a contact device placed upon the escapement wheel so that there is no apparent frictional resistance, and the clock keeps true time. That clock I found was first used on the experiments made by the Westinghouse Air Brake Company on the Lehigh Valley road—tests in competition between the Westinghouse and the New York Air Brake companies for recording the intervals of time between the application of the brake on the engine and the application of the brake on the rear car of a fifty-car train. I took advantage of Mr. Park's experience and expense and went to the same man with identically the same kind of a clock. He fixed the clock for

me, and it apparently keeps accurate and correct time as near as a first-class Seth Thomas clock can keep it.

The advantage of the apparatus which I have described over the one used by Professor Langley is that Professor Langley's apparatus is very elaborate and very expensive, and was devised for the express purpose of recording minute intervals of time upon his whirling-machine test at the Allegheny Observatory, and afterwards at the Smithsonian Institution. The full description of that instrument is in a paper published by the Smithsonian Institution on aërodynamics, by Professor Langley, I think in 1897 or 1898; but the apparatus which I described is one of which the clock can be prepared in three days' time and the rest of it bought in the open market.

*Mr. F. B. Corey**.—In reviewing the discussion of this paper I wish to again emphasize the statements made in the last paragraph, in which attention was called to the fact that the instrument described does not belong to the class known as precision instruments. The instrument as described is, however, a useful addition to railway testing apparatus, the degree of approximation being sufficient for most conditions under which such an instrument is used.

There is an error in the method of calibration, but not such as suggested by Mr. Whittemore, as it is not a constant depending on the specific gravity of the liquids or the relative lengths of the tubes. The percentage of error is a variable, being equal to the versed sine of the angle of inclination. This error is practically negligible for an instrument of this class, being less than three-tenths of one per cent. for an acceleration due to a force of 150 pounds per ton.

The instrument shown by Mr. Lewis is a very interesting and very different means of arriving at a similar result. The best method to determine the relative advantages of each is indicated by Mr. Lewis's suggestion of a comparative test.

I fear that the photograph of the recording apparatus is not sufficiently clear, as the method of making the record does not seem to be well understood. I certainly would second Mr. Fowler's statement that any instrument depending upon a record, the making of which involves the diversion of the operator's eye from the instrument to the paper, is not only "absolutely and totally

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* Author's closure, under the Rules.

unreliable," but utterly worthless as a record instrument. While the method of recording used in this instrument is by no means ideal, the results show that it is sufficiently good for most purposes. Exactly the same method has been used for several years to secure ammeter records, and the method has been found to give results far superior to any form of automatically recording ammeter yet devised. The "personal equation" has been found to introduce a far less error than exists in the less sensitive and more complicated instruments in which this equation has been eliminated.

No. 928.*

A BONUS SYSTEM OF REWARDING LABOR.†

BEING A SYSTEM OF TASK WORK, WITH INSTRUCTION CARDS AND A BONUS.

BY H. L. GANTT, SO. BETHLEHEM, PA.
(Member of the Society.)

1. THE system described in this paper has recently been introduced by the writer into the large machine shop of the Bethlehem Steel Company, and has met with such unqualified success that a description of it would seem to be of interest to the Society.

2. *Aim of System.*—It is an attempt at harmonizing the interests of the employer and employee, and, while it affords substantial justice to the employee, requires that he shall always conform to the best interests of his employer. That it accomplishes such a result, at least in a measure, is shown by the fact that it has caused a complete change in the whole atmosphere of a shop, notwithstanding the fact that it has been in operation for a few months only.

3. *Description of System.*—A card is made out, showing in detail the best method (so far as our present knowledge goes on the subject) of performing each of the elementary operations on any piece of work, specifying the tools to be used, and setting the time needed for each of these operations as determined by experiments. The sum of these times is the total time needed

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* Presented at the New York meeting (December, 1901) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For previous discussions on this topic consult *Transactions* as follows:

No. 256, vol. viii., p. 630: "A Problem in Profit Sharing." Wm. Kent.

No. 341, vol. x., p. 600: "Gain Sharing." Henry R. Towne.

No. 459, vol. xii., p. 755: "The Premium Plan of Paying for Labor." F. A. Halsey.

No. 647, vol. xvi., p. 856: "A Piece Rate System." Fred. W. Taylor.

to complete the piece of work. If the man follows his instructions, and accomplishes all the work laid out for him, as constituting his proper task for the day, he is paid a definite bonus in addition to the day rate which he always gets. If, however, at the end of the day, he has failed to accomplish all of the work laid out, he does not get his bonus, but simply his day rate. As the time for each detail operation is stated on the instruction card, the workman can see continually whether he is earning his bonus or not, and if he finds any operation which cannot be done in the time set, he must at once report it to his foreman. If, on careful investigation by the man making out the card, the workman's statement is found to be correct—that a portion of the task can not be done in the time stated on the card—a new instruction card is made out, explaining the proper method of working, and allowing the proper time. It is of the greatest possible importance for the moral effect upon the men that errors in making out instruction cards should be as few as possible. A man must be allowed time only for what is stated on his card, and while a reasonable time must be allowed for each operation, he should fail to receive his bonus if time is lost from any cause whatever. (The foremen also receive, in addition to their day wages, compensation proportional to the number of their men who earn a bonus, and an extra compensation if all of their men earn their bonuses.)

As these cards are made out by a skilful man, with the records at hand, they invariably prescribe a better method for doing the work than the ordinary workman or foreman could devise on the spur of the moment. As all the appliances and instructions necessary for doing the work are furnished, and a fixed premium or bonus is allowed the workman in addition to his regular rate if the work is done satisfactorily in the time set, it will be seen at once that this method is really a system of education, with prizes for those who learn, and the results already obtained bear out this idea of education most fully, for under it men have learned more in a few months than they ever did before in years.

4. *A Differential System.*—A careful consideration of this system will show that, while it is not a system of piece work, it has many of the advantages of differential piece work, by which I mean that the compensation is *quite large for the maximum amount of work obtainable, and quite small for anything less than*

this amount. For instance, if a man does all that is asked of him, which must always be possible, he gets a large extra reward; but he gets no reward, except his ordinary day rate, if he falls short of this amount. The extra bonus which the bosses earn when all of their men perform the maximum amount of work is a strong inducement to make them teach their inferior men.

5. *Breakdowns.*—Again, as it is impossible for the men to earn their bonuses when their machines are out of order, it furnishes an automatic punishment for breakdowns, for the man not only loses his bonus on the day the machine breaks down, but on all subsequent days until the machine is running satisfactorily again.

6. *Basis of System.*—This system is, so far as the writer is aware, a new one, but is based on the principles of Mr. Fred. W. Taylor's system of elementary rate fixing (see paper No. 647, "A Piece Rate System," *Transactions*, vol. xvi., p. 856), and is as far as possible removed from the old fashioned method of fixing piece rates from records of the total time it has taken to do a job. It possesses an advantage over direct piece work in that it is more flexible and can be introduced with greater ease and under conditions where piece work proper would be impossible. When it is realized that proper piece work will, in many cases, produce at least three or four times as large an output as ordinary day work, the difficulties of putting directly on piece work men who have been accustomed to doing work in their own way and in their own time would seem to be, and generally is, extremely difficult. While the men who are on day work usually realize that they are not doing all they can do, when they are told that it is possible to do three or four times as much as they are doing they simply do not believe it, and it is very difficult to make them accept as just a piece rate founded on this basis; but a reward in addition to their day rate constantly held before them will finally be striven for by some one, and when one has obtained it others will try for it. In other words, if the instruction card is made out and a substantial bonus offered, time will do the rest.

7. *Scientific Method.*—In order to get the information necessary to fix proper piece rates, or even to make out good instruction cards, a very large amount of detail work is necessary. When we realize, however, that any operation, no matter how

complicated, can be resolved into a series of simple operations, we have grasped the key to the solution of many problems. Further study leads us to the conclusion that many complicated operations are composed of a number of the same simple operations performed in a different order, and frequently that the number of elementary operations is smaller than the number of complicated operations of which they form the parts. The logical method, therefore, of studying a complicated operation is undoubtedly to study the simple operations of which it is composed, a thorough knowledge of which will always throw a great deal of light on the complex operation. In other words, the time needed for performing any complex operation must necessarily depend upon the time and method of performing the simple operations of which it is composed. The natural method, then, of informing ourselves about a complex operation is to study its component elementary operations. Such study divides itself into three parts, as follows:

An analysis of the operation into its elements.

A study of these elements separately.

A synthesis, or putting together the results of our study.

This is recognized at once as simply the ordinary scientific method of procedure when it is desired to make any kind of an investigation, and it is well known to all that until this method was known and adopted science made practically no progress, and the writer believes that if it is desired to obtain the correct solution of any problem we must follow the well-beaten paths of scientific investigation, which alone have led to reliable results. The ordinary man, whether mechanic or laborer, if left to himself, seldom performs any operation in the manner most economical, either of time or labor, and it has been conclusively proven that even on ordinary day work a very decided advantage can be gained by giving the men instructions as to how to perform the work they are set to do, and, when these instructions are the result of scientific investigation, the gain in efficiency is usually beyond our highest expectations.

8. It is perfectly well known that nearly every operation can be, and in actual work is, performed in a number of different ways; but it is self-evident that all of these ways are not equally efficient, when we consider that the object to be attained is to accomplish the greatest amount of work in the shortest time, and with as little expenditure of energy as is consistent with

quickest work As a rule, some of the methods employed are so obviously inefficient that they may be discarded at once, but it is often a problem of considerable difficulty to find out the very best method, and it is only by a scientific investigation of all the elements of the operation that we can hope to arrive at even an approximate solution of the problem.

9. Mr. Fred. W. Taylor, who was the pioneer in this work of elementary rate fixing which involves complete detailed instructions, began to work on these lines in 1880, and soon became convinced that they were correct. He has fixed a large number of rates, all of which are lower than those usually paid, but as he takes care to furnish the best implements for doing the work, and insists that the work shall be done as he instructs, the good men always make better wages than they can where they are allowed to do the work with the implements and in the manner they see fit. His piece rates, founded on careful investigation, and with an earnest attempt to do justice both to the employer and the employee, have produced not only a much greater output than any other method in the works where they have been introduced, but a much better feeling among the men towards their employers. The fact that during the past twenty years a great many such rates have been introduced, always with the same result, is a confirmation of the correctness of the principles on which they are based, and leads us to the conclusion that a strict adherence to these principles and a desire on the part of employers to do substantial justice to their employees, would in a short time materially lessen the antagonism between employers and employees which seems at present to be so prevalent.

The scientific method of investigation of the elements into which every operation may be divided, is then evidently a satisfactory basis for fixing piece rates, and it should always be employed whenever it is desired that the rates shall be permanent. To analyze every job and to make out instructions as to how to perform each of the elementary operations requires a great deal of knowledge, much of which is very difficult to acquire; but the results obtained by this method of working are so great that the expenditure to acquire the knowledge is comparatively insignificant.

In this connection, it is, perhaps, well to call attention to the article on "The Taylor-White Process of Treating Tool Steel,"

by Mr. Charles Day, in the September number of the Journal of the Franklin Institute, in which he makes a strong plea for scientific investigation. Mr. Day's criticism of the ordinary guess-work methods may be severe, but when the difference between guess and scientific investigation has been fully realized, it will seem very mild.

10. *Instruction Cards.*—When a piece rate is made out for any kind of work with which the men are not thoroughly familiar, it is obviously only simple justice to them that they should have detailed instructions as to the way to accomplish each of the elements of the work in the time needed to earn fair wages. Permanent piece rates can be made out only when the instructions are such as will accomplish the work in the minimum time, and to get sufficient information to make out instruction cards suitable for a piece rate basis is often a long and tedious operation. On the other hand, instruction cards may be made out to show the best method of doing the work which we can devise with our present knowledge and appliances. Such cards will seldom represent the very best method of performing the work, but will usually represent a method far superior to that which the ordinary workman would employ, and if we can get the men to do the work as directed on these cards, we can very largely increase the efficiency of their work. This is a most obvious way of increasing our output when we have not sufficient information to make out permanent piece rates. To base a piece rate on such an instruction card would be simply inviting trouble, as but few men could see that it was just to change a piece rate when we changed the method of doing the work. If, on the other hand, we allow the men their day rate and offer them a bonus or premium for doing the work in accordance with our instruction cards, they see at once that they have nothing to lose by conforming to our wishes, and all to gain, with the result that they will in a short time make an effort to do the work in the manner and time set. As we stated in advance, these instruction cards do not necessarily represent the best possible method of doing the work, but the best method which we could devise at the time, and we have found that there is practically no objection on the part of the men to a change of time on these cards, so long as the new time corresponds to a new set of instructions which will enable them to perform the work in the time set.

It is hard to over-estimate the value of a complete set of instructions showing the best method of performing a piece of work, and when we come to consider the question of piece work, the payment of a bonus, or, in fact, any method of compensation except that of straight day work, proper instructions embodying our best knowledge on the subject are absolutely essential, if we wish to obtain the best results.

11. *Application of Instruction Cards to a Machine Shop.*—In order to make proper instruction cards for a machine shop doing a variety of work, it is necessary to know the laws of the cutting of metals, as well as the time for handling work in this particular shop. The laws referred to are very complicated, but here again, Mr. Taylor has made such a start as to render it possible to determine the best method and time for rough-machining steel. The results of his experiments on lathes were reduced to a slide rule by the writer for convenient use. This slide rule has been improved by Mr. Carl G. Barth, who has also extended it to planers, drill presses, and slotters, and who made out slide rules for a number of machines in the large machine shop of the Bethlehem Steel Company. By means of these slide rules we can determine promptly the most economical feed and speed with which to perform any operation on a piece of steel when the physical qualities of the steel are given. As an illustration of exactly how instruction cards are made out in a machine shop, we may cite the case of a forging that has to be rough-machined. The drawing first goes to an expert mechanic, who has charge of what is known as the routing of the piece through the shop. He decides the order in which the various operations of turning, planing, slotting, drilling, etc., are to be done. In a shop doing a variety of work, too much stress cannot be laid on the routing, for, besides the advantage of knowing in the office the progress of the work, the saving made by performing the various operations in the best order is very great. This subject of routing is large enough to take up a paper by itself, so it can only be mentioned here. If the first operation to be performed is that of turning, the forging is assigned to the lathe best fitted for handling this particular job. The work to be done on the machine is then analyzed by a first-class machinist, who has been instructed in the use of the slide rule, and who makes out an instruction card on which the operations to be performed on this lathe are placed in the proper order, with

proper instructions, the calculated time being given for performing each operation. The kind of tool to be used, the feed, and speed are specified for every machine operation. For every other operation, such as putting in and taking out work, laying out, changing feed gears, etc., instructions are given, and the time that each should take is placed directly opposite the description, in a column designed for that purpose. Fig. 144 is a sample card for rough-turning a locomotive piston rod:

12. This card represents instructions given to William Jones, whose boss is Thomas Smith, to do work on Forging No. 14,653C4, Manufacturing Order No. 17,344, in Lathe No. 145, according to Standing Order No. 376. The hardness of the metal is represented by class 12. He must use tools made of "M E" steel, of the shape designated in the column calling for shape of tool. The approximate depth of cut in turning is $\frac{3}{16}$ inch. "J" represents a combination of feed gears, and "2-BF" a cone speed which he must use. Opposite each operation are seen complete instructions giving the kind of tool, cut, feed, and speed that must be used in order to accomplish the work in the time set. The total time for turning and facing this forging is shown to be forty-two minutes. At the bottom of this card is given, first its number, then the drawing number of the assembling sheet, if we have such a sheet; then the detail drawing for this particular piece, and next the date and signature of the man who made out the card. The note at the bottom, namely: "When machine cannot be run as ordered, speed boss must at once report to the man who signed this slip," is put on in red ink and should be observed to the letter.

By means of this card filled out from the slide rule, together with records of the time necessary to do miscellaneous operations, which for simplicity we shall call "hand work," we can instruct a very ordinary man in the best method of doing any job of this character. Considerable training, of course, is necessary to teach the men, who, as a rule, are ordinary laborers, to follow these cards. Having once given them this training, however, the advantage of having a first-class machinist to do the thinking, and to use for them the best results already obtained, produces an efficiency which would be absolutely impossible if the workmen were left to themselves.

13. For further illustration I give three more cards (Figs. 145–

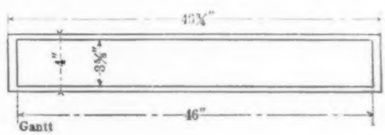
DM 36-5000-8, 6, 1901.

CLASS OF WORK		STANDING ORDER	ORDER NUMBER
Lathe		*376*	*17344*
MACHINE NO.	**TOOL**	**CLASS OF METAL**	**FORGING NUMBER**
145	M E H	*12*	*14653c 4*

MAN'S NAME *Wm. Jones* SPEED BOSS *Thos. Smith*

	DESCRIPTION OF OPERATION	SHAPE OF TOOL	CUT	FEED	SPEED	TIME WORK SHOULD TAKE	TIME WORK DID TAKE	RATE
1	*Chuck*					*2.5*		
2	*Face end*	*P V M*			*2 B F*	*4.0*		
3	*Turn half way*	*P R L*	$\frac{3}{16}$	*J*	"	*12.0*		
4	" *end for end*					*5.0*		
5	" *half way*	*P R L*	$\frac{3}{16}$	*J*	"	*12.0*		
6	*Face end*	*P V M*			"	*4.0*		
7	*Remove from machine*					*2.5*		
8						*42.0*		
9								
10								

Inside lines in sketch represent machined, and outside lines forged, sizes.



NOTE.—Sketches are not usually put on the instruction cards, but are put on here for convenience.

INSTRUCTION CARD NO	SHEET DRAWING NO.	B. S. CO DRAWING NO.	MONTH	DAY	YEAR	SIGNED
4327		*26627¼c*	*6*	*1*	*1901*	*Buckley*

WHEN MACHINE CAN NOT BE RUN AS ORDERED, SPEED BOSS MUST AT ONCE REPORT TO MAN WHO SIGNED THIS SLIP.

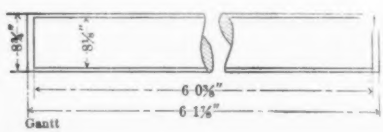
FIG. 144.

DM 36-5000-8, 6, 1901.

CLASS OF WORK		STANDING ORDER	ORDER NUMBER
Lathe		*580*	*17058*
MACHINE NO.	**TOOL**	**CLASS OF METAL**	**FORGING NUMBER**
76	M E H	*16*	*22834 B 1 F 2*

MAN'S NAME.................................... SPEED BOSS....................................

	DESCRIPTION OF OPERATION	SHAPE OF TOOL	CUT	FEED	SPEED	TIME WORK SHOULD TAKE	TIME WORK DID TAKE	RATE
	Change machine 10 minutes (for 1st one only)							
1	*Chuck*					*04*		
2	*Turn half way*	*P R L*	*¾"*	*E*	*3 A F*	*30*		
3	*Face end*	*P V M*			"	*17*		
4	*Turn end for end*					*06*		
5	*Face end*	"			"	*17*		
6	*Turn half way*	*P R L*	"	"	"	*30*		
7	*Remove piece*					*03*	*hr. min.*	
8						*1:47*	*1:50*	
9		*(Bonus not earned*						
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21	*Previous*	*time*	*on an*	*other*	*lathe 5*	*½ hrs.*		
22								
23								



INSTRUCTION CARD NO.	SHEET DRAWING NO.	B. S. CO. DRAWING NO.	MONTH	DAY	YEAR	SIGNED
5613	*F C A C*	*25330¼ C*	*9*	*18*	*01*	*Buckley*

WHEN MACHINE CAN NOT BE RUN AS ORDERED, SPEED BOSS MUST AT ONCE REPORT TO MAN WHO SIGNED THIS SLIP.

FIG. 145.

147), which are made out in the same manner as the first one. One of these is for a far more complex operation, and it may be of interest to note that cards are frequently made out that are twice as long as this one.

This system of instruction cards was introduced by the writer into Machine Shop No. 2, of the Bethlehem Steel Company, in June, 1899, with markedly beneficial results, which increased as the men making out the cards became more and more skilful and the cards were made out more and more in detail. There was comparatively little difficulty in causing the men to perform the automatic operations according to the instructions given. For instance, they would run their machines at the feed and speed called for, but the great difficulty was that it seemed impossible to prevent them from losing time between operations. One would frequently find many of the machines idle, and yet every workman could give a more or less plausible excuse why his machine was not running, and this in spite of the fact that tools were ground for him and furnished to him, and the work so prepared that all he had to do was to put it in the machine and begin cutting. In other words, no matter how efficiently the machines were run through their actual working time, the men found good excuses for taking more than the prescribed time on every job, and for wasting enough time to hold down the output of the shop very materially.

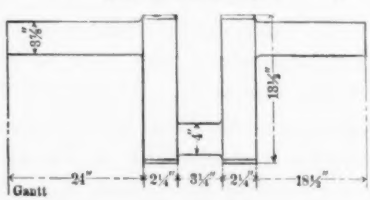
14. *Bonus.*—To overcome this difficulty it was proposed by the writer that every man who succeeded in doing all the work called for by his instruction cards for a complete turn should receive a bonus, or premium. When this payment of a bonus went into effect, the amount of time wasted diminished very rapidly, and soon a majority of the men on the machines were earning their bonuses regularly. In order to be sure that they got all the assistance possible from the foreman, he, too, received a definite premium for each machine under his charge that made its bonus, and in order that the poorer men might receive sufficient instruction from the foreman, it was made to his interest to give them special attention. That was accomplished in this way: While the foreman was given a definite amount for each machine that earned its bonus, he was given an additional fifty per cent. if all the machines under his charge earned their bonus, thus making it to his interest to give special attention to the men most likely to fall behind.

DM 36-5000-8, 6, 1901.

CLASS OF WORK		STANDING ORDER	ORDER NUMBER
Lathe		*460*	*16837*
MACHINE NO.	**TOOL**	**CLASS OF METAL**	**FORGING NUMBER**
59	M E H	*14*	*22706 B 1 F 1*

MAN'S NAME .... SPEED BOSS ....

	DESCRIPTION OF OPERATION	SHAPE OF TOOL	CUT	FEED	SPEED	TIME WORK SHOULD TAKE	TIME WORK DID TAKE	RATE
	Change machine 20 minutes (for 1st one only)							
1	*Chuck for turning webs*					*12*		
2	*Turn webs*	*P R L*	*3 cuts*	*E*	*4 A F*	*1:40*		
3	*Change to Pin Centres*					*1[illegible]*		
4	*Rough Pin to $4\frac{1}{16}$ dia.*	*P S R*		*0.005*	*5 A F*	*2:10*		
5	*R face webs use double end*	*tool*	*2 cuts*		*4 A F*	*1:40*		
6	*Finish " " " "*	*"*	*1 cut*	*H*	*"*	*50*		
7	*Finish turning pin & cut*	*fillets*		*E*	*2 A F*	*2:00*		
8	*File pin round*					*1:10*		
9	*Polish pin*				*2 B F*	*40*		
10	*Inspect*					*15*		
11	*Remove crank*					*05*	*hr. min.*	
12						*10:52*	*10:50*	
13	*Pin is No. 1*	*finish;*		*webs are No.*		*3 finish*		
14								
15		*(Bonus earned)*						
16								
17								
18								
19								
20								
21	*Previous time 5¼ hours*							
22								
23								



INSTRUCTION CARD NO.	SHEET DRAWING NO.	B. S. CO. DRAWING NO.	MONTH	DAY	YEAR	SIGNED
4811	*F M C B*	*26194½ A*	*7*	*17*	*01*	*Buckley*

WHEN MACHINE CAN NOT BE RUN AS ORDERED, SPEED BOSS MUST AT ONCE REPORT TO MAN WHO SIGNED THIS SLIP.

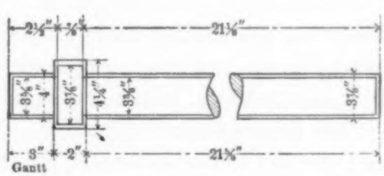
FIG. 146.

DM 36-5000-8, 6, 1901.

CLASS OF WORK		STANDING ORDER	ORDER NUMBER
Lathe		*570*	*17351*
MACHINE NO.	**TOOL**	**CLASS OF METAL**	**FORGING NUMBER**
160	M E H	*15*	*18253 B 1 F 1*

MAN'S NAME.................................... SPEED BOSS....................................

	DESCRIPTION OF OPERATION	SHAPE OF TOOL	CUT	FEED	SPEED	TIME WORK SHOULD TAKE	TIME WORK DID TAKE	RATE
	Change machine 5 minutes (for 1st one only)							
1	*Chuck 3⅝" to F P*					*2½*		
2	*Turn 3⅝" × 21⅛" long*	*P R L*	*¼*	*i*	*2 B F*	*11*		
3	*Face end*	*P V M*			"	*05*		
4	*Turn end for end*					*04¼*		
5	*Face end*	"			"	*05*		
6	*Turn 3⅞" Dia.*	*P R L*	*¼*	"	"	*02*		
7	*Turn 3⅝" "*	"	*¼*	"	"	*03*		
8	*Remove piece*					*2½*		
9						*35*	*3¼ min.*	
10								
11								
12		*(Bonus earned)*						
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								



Previous time taken 1 hr. 6 min.

INSTRUCTION CARD No.	SHEET DRAWING No	B. S. Co. DRAWING No.	MONTH	DAY	YEAR	SIGNED
5368		*6258*	*9*	*12*	*01*	*Buckley*

WHEN MACHINE CAN NOT BE RUN AS ORDERED, SPEED BOSS MUST AT ONCE REPORT TO MAN WHO SIGNED THIS SLIP.

23

FIG. 147.

Results of Bonus.—Inasmuch as no bonus whatever is paid unless the men actually perform the work called for on their instruction cards in the time set, it is to the interests of the men to prevent accidents to the machines, and to avoid unnecessary delays, whether such delays are their own fault or the fault of other people. Among the results we have obtained are:

First. A very large increase in output, averaging from 200 to 300 per cent.

Second. A falling off in accidents and breakdowns.

Third. A quickening of the intelligence of the men.

For instance, men who could formerly do nothing for themselves, but were obliged to ask the foreman all kinds of questions, now find that they can do the work by asking fewer questions, for if they spend a large proportion of their time hunting the foreman they lose their bonus. One man, for instance, who in three years had never learned to change the feed gears of his machine properly without the assistance of his foreman, lost his bonus three days in succession because they had not been properly set. He at once learned to set them, and has had no difficulty from this cause since.

15. *Comparison of Bonus System and Piece Work.*—In making a comparison between the bonus system and proper piece work, it will be recognized at once that each has its advantages. If we have a thorough knowledge of all the conditions, and are able to introduce piece work, it is undoubtedly to be preferred; but we must remember that, aside from the injustice, there is nothing so demoralizing as cutting piece rates, and it is not only extremely difficult to make out proper piece rates, but it is still harder to convince men who have been accustomed to working by the day only, that it is possible for them to earn fair wages when proper rates are set. On the other hand, as the bonus is paid to men in addition to their day rate for performing the work in the manner and time called for by their instruction cards, they do not feel so hostile toward the innovation. These cards do not pretend to represent absolutely the best possible method, but the best method we can devise with the present state of our knowledge, and, while they may be changed as our knowledge increases, they are always intended to describe a method which is within the ability of a good man to reach. The difficulty of introducing such a system is far less than that of introducing direct piece work, for if workmen, having secured to

them their day wages, are given such instruction cards, and a considerable reward is held out to them for doing the work in the manner and time called for in the instruction cards, they will gradually overcome their prejudice against following instructions, and finally attempt to perform some of the operations in the time set. Having performed a few of these operations, and finding out that the card represents a fair and reasonable set of instructions, they will, in a short while, conclude that they might as well have the extra pay, and gradually learn to follow the whole card. This has been the experience of the writer, and he was surprised to find out how quickly the men overcame their prejudice. Before the introduction of the bonus, no man was willing to ask somebody else to hurry in order that he might get his work done, for the man spoken to would resent such a request as an insult. Men seldom complained to a foreman that they were being interfered with, but simply sat down and waited, and would sometimes wait for a crane by the hour. Now all are up in arms against anybody who does not serve them almost instantly.

16. The greatest difficulty to be met is to convince the men that these instruction cards are intended to be such as a man familiar with the work can, by due industry and with a fair amount of intelligence, always follow successfully; but when the men are once convinced that this is a fact, and that it is the intention of the company to allow them to earn the reward indicated for the extra work, most of the difficulties are over. To make out such cards requires an amount of knowledge and experience that is seldom the possession of any one man. To obtain this information requires a long series of detail observations and investigations with corresponding records, and even after having obtained a great deal of such information, most of our instruction cards will still fall far short of perfection. They are intended to represent our best knowledge of how to perform the work, and the man following the card earns his bonus not because he does the job in the best possible way, but because he does it in the manner which the present state of our information indicates is the best. If subsequently to having made out a card for a certain job we have obtained more information on that job, and find an easier and quicker method of doing the work, our instruction cards may be made to conform to the new and better method, but only such items on the instruction card should be

changed as are affected by this new and better method. In other words, no wholesale change in a card is allowable under any conditions. It must be possible always to perform the individual elementary operation in the time set, and when a man complains that he can't do this, he must be asked to point out the individual operation or operations that he can't do; if the foreman cannot show him how to perform these operations in the time set, the matter should at once be referred to the man making out the instruction cards, who must either be able to show how to carry out the instructions given, or change the instruction card so that it can be followed. This throws the responsibility for the success of the system on the man making out the instruction cards, who should not only be a good mechanic, but a man of the highest order of intelligence and integrity, for he practically fixes the pay of the men, and is, in a large degree, responsible for the output of the shop. This is true, whether the instruction cards are made out for a bonus system or for piece work, and unless a proper man is selected to have charge of this work, the whole system, whether that of paying a bonus or piece work, will immediately fall into disrepute. As I have said before, piece work, when proper piece rates can be made, is preferable to a bonus system, but the delay in getting sufficient knowledge to fix permanent piece rates is often so great that it is absolutely necessary to resort to some shorter method for obtaining an increased output, and the bonus system as outlined here, or some modification of it based on the instruction cards, is a very efficient means of accomplishing this end, and one which is easily introduced because it avoids raising issues with the men.

17. The system as described here is specially applicable to work done on automatic machine tools, where efficient running of the tools counts more than manual dexterity. If, on the other hand, the work is such that manual dexterity or strength is the main factor, it will be usually necessary to offer, in addition to the bonus for maximum efficiency, one or more bonuses for definite approximations to this maximum. This, however, is one of the numerous modifications that will suggest itself when a proper system of instruction cards and records has been introduced.

18. *Results of Improved Methods of Management and the Bonus System.*—To show what has already been accomplished, I

append some notes which, of themselves, may be of interest. The first is an official report made to Mr. E. P. Earle by his able assistant, Mr. R. J. Snyder, in less than two months after the bonus system had been started. Mr. Snyder had special charge of the working of the system, and speaks with authority.

BETHLEHEM STEEL CO., Department D. M. — SO. BETHLEHEM, PA., *May* 13, 1901.

MR. E. P. EARLE,
Supt. of Machine Shop, No. 2.

Dear Sir :—I hand you herewith some notes on the results obtained by the introduction of the "bonus" plan for remunerating labor in No. 2 Machine Shop.

The plan thus far has been applied only to the roughing lathes, and I give below a list of the numbers of the machines, with the dates on which they began operating under a bonus or premium :

Lathe, No.	76......March	18, 1901.		Lathe, No.	207......April	3, 1901.
" "	158...... "	19, "		" "	60-A.... "	4, "
" "	159...... "	19, "		" "	60-B.... "	5, "
" "	50-A ... "	19, "		" "	90...... "	8, "
" "	50-B ... "	19, "		" "	30...... "	24, "
" "	145...... "	20, "		" "	55...... "	24, "
" "	146...... "	20, "		" "	72...... "	29, "
" "	160...... "	20, "		" "	73...... "	29, "
" "	208...... "	28, "		" "	4-A....May	6, "
				" "	4-B.... "	6, "
				" "	34...... "	9, "

One of the best results obtained after a short trial has been the moral effect upon the men. They have had it placed in their power to earn a very substantial increase in wages by a corresponding increase in their productive capacity, and this has given them the feeling that the Company is quite willing to reward the increased effort. They display a willingness to work right up to their capacity, with the knowledge that they are not given impossibilities to perform. This effect has been brought about by the good use of our excellent slide rules in the hands of a number of the most thoroughly practical men, who, when the results which they demand have been declared impossible to obtain, have repeatedly gone out into the shop and themselves demonstrated that the time was ample, by doing the work well within the limits set. All this has inspired the confidence of the shop hands, and the excellent instruction cards sent out are gradually evolving from laborers a most efficient lot of machine hands.

19. The percentage of errors in machining has been very materially reduced, which is unquestionably due to the fact that in order to earn his bonus a man must utilize his brains and faculties to the fullest extent, and so has his attention closely fixed on the work before him, as every move must be made to count. He thus has no time for dreaming, which was, no doubt, the cause of many errors.

The condition of the machines is vastly improved. Much care has been taken to point out to the men that the best results can be obtained only by keeping their machines in good running condition, well lubricated and cleaned. They have not been slow to realize this, and cases of journals cutting fast are very rare, while before the introduction of the "bonus" plan this was a very common occurrence. Breakdowns are also of a less frequent occurrence.

The crane service lately has given us little trouble, and lack of crane service was formerly a constant excuse of the bosses and men for not being able to keep machines filled with work. The improvement in this case arose from the rule laid down that no exceptions or allowances would be made for delays due to this cause.

It is only by the introduction of this "bonus" plan that we have had furnished the automatic incentive for men to work up to their capacity, and to obtain from the machines the product which they are capable of turning out. It has lifted the hands of the Speed Bosses (foremen) and enabled them to act in the capacity for which those positions were created—that of instructors.

These are some of the direct results obtained. Indirectly it has eliminated the constant necessity for driving the men, and has enabled the shop management to divert some of its energy into perfecting the organization, which only will enable us to give a good account of the shop equipment. Much good has also resulted from putting the work through in lots, and in keeping each machine as nearly as possible on the same kind of work.

It is also a pleasure to note in this connection the deep interest taken in this work by the men connected with it, and the fine coöperative spirit which prevails among all hands.

Yours truly,

(Signed) R. J. SNYDER.

20. The following table shows the reduction of actual machining time under improved methods of management, and the introduction of instruction cards and a bonus system.

Column No. 1 gives the time taken to do work under the old system of day work, where one foreman had charge of a large number of men, and each man was left practically to himself, to do the work the best way he could with whatever tools he saw fit, and to keep his machine in the condition he preferred.

Column No. 2 gives the time taken to do the same work, when a proper number of trained foremen (speed bosses) had been appointed, a proper system of caring for belts and machines adopted, and proper appliances and instruction cards furnished the men.

Column No. 3 represents the time after the bonus system had been applied to the conditions of Column No. 2.

This work was all done under the supervision of Mr. Fred. W. Taylor, who became associated with the Bethlehem Iron

Company in May, 1898, for the purpose of introducing improved methods.

BETHLEHEM STEEL COMPANY, Department D. M.
May 23, 1901.

STATEMENT OF MACHINE TIME REQUIRED FOR ROUGH-TURNING FORGINGS.

Description.	Machine Time in Hours.		
	Prior to 1898, when a beginning was made to introduce improved methods. Day Rate. No. 1.	Immediately before the introduction of the Bonus Plan for rewarding labor. Day Rate. No. 2.	Under the Bonus Plan. No. 3.
4-in. U. S. Navy Tubes	21.56	None machined	5.4
4 " " Jackets	35.15	"	7.1
6 " " Tubes	34.75	18.5	8.25
8 " " "	35.00	None machined	8.00
12 " " "	54.50	32.5	21.50
12 " " Jackets	123.70	65.5	43.33
12 " " A Hoops	No record.	50.75	34.50
12 " " B "	"	55.00	34.75
12 " " C "	"	47.50	34.50
12 " " D "	"	96.50	73.25
Ball & Wood Crank Shafts	"	46.5	26.25
Acme Cam Shafts	"	31.3	16.00
Clayton Double Throw Crank Shafts	"	22.3	4.3
Bement, Miles Piston Rods	"	13.00	3.2
S. Pacific Axles	"	4.25	1.5
C. R. R. of N. J. Driving Axles	"	6.5	1.5
Norfolk & Western Crank Pins	"	2.5	1.25
DeLa Vergne Piston Rods	"	22.0	5.0
Crank Shafts, N. Y. Shipbuilding Company	"	70.	28.75

While the table just given is of interest, as showing in detail what has been accomplished, a more correct measure is afforded by the output of the shop.

During the year from March 1, 1900, to March 1, 1901, the machine shop was run day and night as hard as the machines could be pushed by day work alone, and still the increasing output of the forge was piling up work ahead of it. It was at this juncture that the bonus system was put in operation, as stated in Mr. Snyder's report. To realize what happened in the few months after the introduction of the bonus, it is, perhaps, best to compare the shipments during those months with the average monthly shipments for the preceding year. I do not feel at liberty to give the actual shipments, but if we represent by unity the average monthly output of the shop during

the year from March 1, 1900, to March 1, 1901, the following figures will represent the output for the five months succeeding the introduction of the bonus system :

Average shipments per month for year from March 1, 1900, to March 1, 1901	1.00
Shipped in March, 1901	1.25
" " April, "	1.53
" " May, "	1.86
" " June, "	1.98
" " July, "	2.17

The bulk of the above shipments consisted of rough-machined forgings, and before the end of July the machine shop had caught up to the forge so closely that there was not enough work to keep all the machines running day and night, and a large number were shut down on the night turn. The output of the shop during August was far below that of July, for the reason that the forge did not furnish anything like work enough to keep it busy.

21. *A Needed Addition.*—Although the results as above pointed out are very far in excess of what was anticipated, the writer does not feel that we have yet taken advantage of all our opportunities. As before stated, the system is one of education, with prizes for those who learn; but the prizes have so far been awarded for learning and doing only what our experts already knew. The next and most obvious step is to make it to the interest of the *men to learn more than their cards can teach them.* So far nothing has been done in this line, not because the need for some such provision has not been felt, but for the reason that no entirely satisfactory method has suggested itself.

The writer believes in paying a liberal compensation for improved methods of work, and in offering special inducements to a workman to make out instruction cards, by which others are enabled to carry out his methods. The compensation should be sufficiently liberal not only to induce him to part with what information he may have, but to use his ingenuity to devise better methods.

If this can be properly carried out, the most difficult problem of the system—that of training men to make out instruction cards—will have been solved, and the system will not only become self-perpetuating, but will automatically pick out the men best suited to carry it forward.

DISCUSSION.

Dr. R. H. Thurston.—Any "System of Rewarding Labor" proportionally to its deserts must have great interest to every one, and particularly to the mechanical engineer, whose whole experience and training have shown him, better than anyone else, what serious matters are determined by the questions involved. Our present common wage-system must inevitably be improved upon in the coming decade if we are to avoid very grave disturbances in our social system. Clouds have been gathering for a half-century, and are growing more numerous and darker continually. A storm will surely come if a pleasanter atmosphere is not the result of the efforts of wise and thoughtful men in the immediate future.

The basis of any new adjustment of the relations of employer and employee—of labor and capital as the demagogue and the economist alike are fond of denominating the two fundamental elements of production—must undoubtedly be found in some method of giving to every man a fair return for his time and labor, whether of brain or muscle. The only possible basis of such adjustment of compensation must be the payment to the worker the full value of what he gives, the true market value of his productivity. It is as inequitable to pay a common wage to the skilful and the unskilled alike as it is to pay much for inefficiency and little for high productive power. The apportionment of compensation to the value of the work performed is, it would seem, the form which the problem has assumed.

If this be the fact, it is evident that compensation must be made upon some basis of measurement and valuation of the product of the day's work of each individual. Only thus can each man be properly compensated for what he accomplishes. Piece-work, profit-sharing, and a variable wage are different methods of approximating this ideal, and either or all of these methods of proportioning the gain of the worker to the gain of the employer and of the business may perhaps find place in the development of the perfectly fair system which must be somehow found and ultimately and generally adopted.

The method here described has at least the undeniable virtue of inducing intelligent and industrious coöperation of the employees. It has also one or two peculiarly interesting and promising features in its stimulation of the ingenuity of all concerned in the

effort to find the best ways of efficiently employing machine-tools, in its application of scientific method to this business, in its insurance of coöperation of all grades of employees, in the effort to secure a maximum production with a given plant, and in its payment of a special premium for the successful application of its best methods. The coöperation of the foremen with their workmen is by this system assured, and, as experience seems to have proved, most effectively. While it does not provide a continuous sliding scale of adjustment of compensation to productivity, it at least does give the assurance to the workman that his best efforts will be rewarded handsomely.

Further, it provides a system of education of workmen and foremen and employer alike, through systematic and scientific investigation of the conditions favorable to best use of tools and plant, and to highest returns on invested capital and contributed labor. Where scientific method and systematic education go together much may be hoped for. That such anticipations are justified is admirably proved by the table at the end of this paper, exhibiting the gains by successive improvements in method at the Bethlehem Steel Company's works. Doubling the efficiency of productive machinery and labor by improvement in methods, and again doubling it in many cases by the introduction of the "Bonus Plan" as shown in that table, not only means an immense gain to all concerned but it shows most strikingly the marvellous inefficiency of customary methods of production.

This method involves evidently much work of brain in its inception, and compels the complete coöperation of brain work with work of the hands in its operation; but this has its advantages, and a great advantage in its stimulation of the sluggish brain to do its part, and especially in the conversion of the dull and indifferent worker into an alert and thinking man. It is plain, in the light of Mr. Snyder's testimony, that full compensation is given for all the time, trouble and thought which it compels. Anything which sets the average man thinking profitably is valuable. As a rule, the average human being does not do much thinking, and what little he does is not apt to be very profitable. The paper seems to me to be an important contribution to the proceedings of the Society.

Mr. F. A. Halsey.—It seems to me that the feature of this system about which we need to know more is Mr. Taylor's elementary rate-fixing department. This is referred to in the pres-

ent paper and also in Mr. Taylor's paper, "A Piece Rate System," published in Vol. XVI. of the *Transactions*, but in neither case is the matter gone into with sufficient detail to enable others to use the method. What especially puzzles me is to imagine how, from the results of every-day work, the maximum possible results can be predicted.

There are several features of the work at Bethlehem which should not be lost sight of: First, the work is all large, much of it is very large, and some of it may be described as the largest; Second, the work is chiefly on forgings, and consequently the shapes are simple; Third, these forgings are usually rough finished only, a fact which reduces the estimate for the time required for a given piece of work to a mere matter of extent of surface and depth of cut; Fourth, the material is made upon the ground and its qualities, as regards hardness and workability, are thus well known and have, in fact, been reduced to a scale depending upon composition; Fifth, while there is a general similarity running through much of the work a given piece is seldom repeated, a fact which makes the setting of a time limit by estimate a matter of necessity if it is to be done at all. The fact that the work is large makes it possible to spend an amount of time and expense in determining these matters which would be economically impossible with miscellaneous small pieces, and the facts that the shapes are simple, that the cuts are roughing cuts only, and that the workability of the material is known, make it more feasible to get at the data for these calculations than would be the case with miscellaneous work.

In view of the results exhibited it would be a very unprofitable task to endeavor to point out spots on the sun, but it seems to me that while the system has undoubtedly accomplished great things at Bethlehem, its field is nevertheless limited.

I do not feel like making an extended comparison between this system and the premium system, but it may be worth while to point out that the essential difference lies in the fact that with the premium plan the *average* results are taken as a basis, and the workman is then offered a premium for improving upon those results, whereas with this system the *maximum* results are first obtained by estimate, and the workman is then offered a bonus if he will reach those maximum results. In other words, the average results are the basis of one system, while the maximum results are the basis of the other. The finding of the average results is, of

course, a simple matter of observation, while the finding of the maximum results is a matter of extended analysis and calculation.

I have never presented the premium plan as a perfect thing nor as an ideal thing, and certainly not as the only good thing. On the contrary, its chief merits lie in the fact that it is a simple thing and a flexible thing, and it is to-day in use by many men and in many places, where the elaborate nature of Mr. Taylor's ideas would prevent them from being even considered.

Mr. Charles Day.—The very able paper which Mr. Gantt has just read opens up so many new fields for thought that I hardly know where to begin the discussion.

He has offered a solution to one of the most trying problems with which the employer has to deal, namely—obtaining the maximum output from a body of men in a manner which divides the return as justly as possible between the employer and the employee. Without some such system our modern machine-shop equipment amounts to little; and, although many excellent suggestions have been made and successfully carried out in the form of piece rates and premium plans, the present paper seems to me to be far ahead of anything yet offered, as it is based on fact, instead of fiction, and will grow as our knowledge grows. It possesses the good features of the older methods, as far as the bonus is concerned, and also offers the only *real* way of setting a rate, *i. e.*, analyzing the complex operation into its elements, and studying them as such. It seems to me that the man is the machine we must first consider, and to increase his output with the facilities at hand, he must be stimulated through the awakening of the intellect, covetousness, pride, or other motive. Mallock tells us that but 6 per cent. of men work intelligently, the rest being laborers, very good laborers, however, if given the necessary instruction and incentive. This is what the present scheme aims at. We must study the "personal equation" of the average man, and there we will find that instinct, not intelligence, plays the more important part. Once firmly fix in the workman's mind that we are working for his interest, as well as our own, and the battle is nearly won. But, in order to maintain this feeling, very few mistakes in rates should be made, and it must be possible, as conditions change, to alter such rates without endangering your position.

There are two distinct classes of machine shops—

First.—Shops that do duplicate work only.

Second.—Shops that do work of a general character. The Westinghouse Air-Brake Company, and the Westinghouse Machine Company have been referred to in this respect, and better examples could not be cited.

In the former works, where a series of operations are repeated thousands of times, the *best-known* practice is sure to be adopted, and the cost of production is reduced to a minimum. In the machine-works, on the other hand, the conditions are reversed; each job, speaking generally, is an experiment, and, if repeated often, could be done to better advantage. It is the solution of this problem which is brought out so clearly by Mr. Gantt. By starting at the bottom, obtaining an absolute knowledge of the elements with which we are dealing, and applying this information correctly, it is possible to machine the most complicated form in the least possible time. It places the two shops in the same class, so far as efficiency goes, and adds a very strong feature to the first, *i. e.*, the ease with which rates can be changed to meet new conditions. This has always been one of the weak points of the piece-rate system, and, as nothing is undergoing more rapid evolution than the machine shop, it is a constant point of contention.

In order to see how far-reaching is the influence of this "scientific investigation," when properly carried out, I will go into the details of a given piece of work. If of steel, it must, of course, be of a given chemical composition and undergo a certain process of annealing. If these specifications are not followed out very closely, the instructions given the machine shop will not hold, and the forge department will be called to account, the consequence being much greater uniformity of material, one of the first essentials of maximum output.

In order to give the necessary instructions to the workmen, a perfect knowledge of each tool must be obtained, and in this connection I am sure that a description by Mr. Gantt of the slide rules, now in use at the Bethlehem Steel Works, would be a revelation to many tool builders.

How many of our machines are built upon scientific principles, and how many manufacturers can inform us of the cuts and feeds a given tool can take? But we must have all this information, and much more, if the "bonus system" described by Mr. Gantt, is to be adopted. I feel sure that tools will be purchased in the future very differently from past custom. First, we wish to know

what a tool will do, and, second, what it will handle. For instance, a 16-inch engine lathe conveys, I think, about the same impression to us all; but I recently saw a 16-inch lathe driven by a 60 horse-power motor, designed to take a cut 3 inches deep, $\frac{1}{16}$-inch feed at 70 feet cutting speed on 30 carbon steel.

It seems strange, indeed, that the machine tool-builders should have to give the credit of first determining the relations between feed, speed and depth of cut for a given material to Mr. Fred Taylor; but now that the way is opened, let us hope that they will use this knowledge to advantage and aid in every way the shop manager who, at present, must content himself by using to the best advantage what he can get, instead of having machines designed for a given duty, and embodying the principles of maximum output. The necessity for close speed and feed regulation and ease of obtaining the same, is shown in its *true light*, when the work is subdivided in the manner explained by Mr. Gantt; and, in fact, any number of similar cases could be cited, but they are all very apparent when we reason along scientific lines, instead of jumping at conclusions. It is this point to which I wish to call special attention—the intelligent design of machine tools; and, although I realize that lathes, drill-presses, etc., must be made in large quantity for a great variety of work, should not the builder be able to state all the more surely the capabilities of such a tool?

Of course, the user must be educated to this standard, but is not the builder the party to undertake this work for his own good?

I feel confident that sufficient proof that the principles as stated by Mr. Gantt are correct, is found in the tremendous increase in output at the Bethlehem Steel Works, and the splendid attitude of the men. At the works of the Link-Belt Engineering Company, Nicetown, Philadelphia, we are endeavoring to follow out the same general scheme, using a modification of the Taylor differential piece-work system.

Mr. C. H. Buckley.—Some may think, after reading Mr. Gantt's excellent description of this system, that even with this plan some of the troubles might arise that often accompany the introduction of a piece-rate system, but my experience proves the contrary.

I have seen men who felt their inability to earn the prize at once, work for it in vain for three days in succession to have their efforts crowned with success on the fourth day.

That workmen are less liable to make mistakes when following instructions may be illustrated by the case of a man who was under me, both before and after the instruction-card system was introduced. Although he had been a helper on one of the large lathes, and had been assigned to me to run a 30-inch lathe, he proved to be so extremely ignorant and stupid that it took a very large amount of my time looking after him.

It made no difference to him where he started on a job ; if there were five pieces in a lot, no two would be machined by the same method, unless I saw specially that it was done, and his tendency to make mistakes was such that I dared not be away from him many minutes at a time.

When, however, he began to receive instruction cards, and had a path laid out for him to follow explicitly on each piece, the difficulties all vanished, and after one week's experience with the instruction cards he could perform the work on a single piece, for which he had a card, almost as quickly as if it were the last piece in a lot of twenty.

That rapid work is necessarily conducive to errors is not in accord either with my observation of others or my own experience as a workman; and, if we compare rapid work when using instructions, with slow work without them, the liability to errors is much less in the former than in the latter case. Slow work gives opportunity for the workman to think of other things besides his work, which is a great source of errors.

When the bonus system was first put in operation, men would frequently ask to be allowed to do the work by their own method instead of following the instruction card. When such requests were granted—and this was frequently done for the moral effect—the men worked harder but almost always lost their bonus, illustrating the fact that the guess of a workman is seldom as good as the analysis of an experienced mechanic. I have seen machinists doing the lathe work on a piece with variable diameters begin at one end, and take each diameter in succession, either changing the speed very often or doing the work at a wrong speed, in either case wasting time. They were doing as well as is generally done without taking time to study the matter.

In making out instruction cards for the lathe men we always specify which end of the piece is to be placed next to the face plate, and then select all the diameters which may be turned to the best advantage with one speed and without changing tools.

Then the next group of diameters with another speed, and so on with a definite object in view.

It seems to be human nature to perform the pleasant task first, and to leave the disagreeable part until last. This is noticeable to a marked degree, especially in piece work, when two men are working on opposite turns on the same machine. The first man to work on a new job will often perform the easy or pleasant task first, forcing the other man to take what is left. The instruction card abolishes this practice, as the order of the operations is specified, and neither man can pick or choose, but must perform the operation next in order. From the inspection report made at the end of each shift, it may be seen a month later, when we begin to erect this work, which of the men did the more accurate work or which made an error that may have escaped the notice of the inspector.

As Mr. Gantt has said, it is hard to convince a man that it is possible to do four times as much work as he is already doing, and I will give my experience with some good machinists, of which the following is a sample. When he receives his instruction card he glances at the time allowed for each operation and the total time to finish the piece. He then begins a mental calculation based on his own experience with similar work, the result of which is, "*Impossible.*" A very stupid observer can readily see this stamped on his countenance.

If this is the man's first introduction to the system, we rarely try to convince him of the accuracy of the instruction card, but the next morning will approach him and get him to perform a few of the operations with the stop watch in plain sight. In a short time he sees that nothing unreasonable has been asked, and will nearly always start from that moment working with a good will; when once he earns a bonus we experience no further trouble.

The advantage of the instruction card is particularly apparent when the same operations are to be performed on a lot of say, twenty, duplicate and rather complicated pieces. The busy foreman and the machinist would ordinarily decide upon some fairly good method of doing the work, but they could not possibly know the best method without making a series of experiments. On the other hand a man whose business it is to find out the best way of doing work, and to make out instruction cards accordingly, would on a new job probably make out several cards showing different methods, and finally decide upon the one which he thought best.

Some will ask why not send this man with his wonderful powers of discovering good methods to the shop as a foreman, or let him actually do the work himself. The same logic that demands of a draughtsman to perfect his designs on paper before they are put into metal, should demand that methods of doing work should be perfected as far as possible on paper before they go to the shop.

The saving of money in the latter case is quite comparable to that in the former and in an economically run shop the man who shows *how* the work should be done is nearly as important as the draughtsman who shows *what* should be done.

Mr. Fred. W. Taylor.—The subject of rate-fixing brought up by Mr. Halsey is of such importance that I prefer to present such data as is in my possession in the form of a separate paper, and hope to present this to the Society at a later meeting.

Mr. M. P. Higgins.—I am not only much interested in this paper and the discussion upon it, but I am impressed with the deep importance of the subject.

This paper is so advanced in its suggestion that we are in danger at first of casting it aside as something like a dream of a millennium, which cannot be realized in our machine shops. I believe the "bonus" principle to be so practical and so scientific that it may be said to be of the nature of an epoch-making proposition in the machine shop. It is certainly a surprise to many of us, and the practical importance of it is likely to grow in our minds.

I have faith in it—first, because it is founded upon scientific principles of analysis such as have proved necessary and successful in the advancement of knowledge and its reduction to science; secondly, because it involves an intensified division of labor which has never been attempted before. The importance of applying the best and fittest brain and thought to industrial labor, such as machine shop work, is in my mind, secondary only to the proper schooling for our mechanics. The proper training of our working mechanics in trade schools will fix our position in the industrial world of the future.

I feel greatly obliged to Mr. Gantt for his very valuable paper. It marks a way for advancing and supplementing all manual skill and technical schooling of mechanics that is scientific and almost ideal.

Mr. James M. Dodge.—I desire to say that some years ago the concern with which I have the pleasure of being connected be-

came enamored with Mr. Taylor's personality and shop system. The hardest dose we had to take was the admission, individually and collectively, that the work which we had done for years we did not understand in all its phases; that we must change our methods of thought before we could adopt Mr. Taylor's system. We endeavored to follow his teachings, and were fortunate in securing the services of Mr. Louis S. Wright, one of Mr. Taylor's earliest assistants. The first thing we stumbled over was our natural tendency to use our past knowledge and experience in mild opposition to the radical changes which we were called upon to make. When Mr. Wright would say, "I am going to put a clerk over there and he is to have a ticket," we would inquire, "What for?" He would then say, "That is part of the system." Some one would possibly suggest, "Why can't you let Billy do that." Mr. Wright would then tell us "that he had other plans for using Billy." So we ran against differences of opinion from the start. Finally Mr. Taylor suggested to us "that we give Mr. Wright full swing, let him do whatever he wanted to do without question, and after he got all the work done, then if we wished to criticize it as a whole, we would be in position to lop off unnecessary limbs understandingly. If you do this," he said, "I will guarantee you will lop off a great many, but the first thing to do is to introduce the system at any cost of money and cost of pride. It is necessary to put yourself in the back-ground and be a spectator. See how the plan works, with a consciousness that if it does not work properly, it can be annihilated." We followed Mr. Taylor's suggestions and when we were practically through with the introduction of the new order of things, I asked one of our competent men "What our own and previous system had been?" He started to tell me the methods of our own devising and he, by the way, was the man best posted in what we had worked out ourselves. "What I mean by system is, we receive our mail, in it our orders, checks, inquiries, etc. Now, what do we do with our mail?" He began to tell me what our plan was, who opened the mail, who transcribed the orders, what was done after the initial entry, some going to the engineering department, some of them (here he hesitated), well, I will look it up and let you know in a minute." I then asked our superintendent, who was a devotee of Mr. Taylor's system, and who had been very much interested in our own. He, too, got a little mixed up in his explanation. I then called in both, explaining what I was driving at, and stated,

"Neither of you can tell the system of our shop in all its details. Mr. Taylor thinks we ought to make a chart of our new system at all events. They mildly objected on the ground that it was easy enough to get all the information we wanted and it took only a few minutes to do it. I then explained that "I did not want to know it, but only asked to ascertain if you knew it." [Laughter.] They hardly thought a chart was necessary. However, I was humored to the extent that a chart was prepared. We then employed less than 300 men and it took eight weeks to make a chart of what we were doing in our shop. When we got the chart done, we went over it carefully and succeeded in cutting out $3,600 of unnecessary expense in the first hour of our work. The reason we were able to make this cut was that the chart showed us where the lines of our system were crossing and indicated clearly how improvements could be made, but it was beyond the power of any intellect we had in our place to see through the tangle until we had it right down on a piece of paper. We detected at once several instances of duplication.

From that time to this we never make a change in our shop system without consulting the chart and noting it thereon and trace out the possible conflict that may arise. It is a mutilated document now, but it clearly shows the history of the development and modifications, of the improvement of the system as originally put in practice. Mr. Taylor has been a blessing to us, and to-day we are expending about 60 per cent. of the present value of our equipment in order to properly follow his lead and use the Taylor-White steel and shop system, so ably worked out by Mr. Taylor and supplemented by the suggestions of Mr. Gantt. Our only regret is that we cannot immediately accomplish all the changes necessary and get more immediate benefit from the introduction. [Applause.]

Prof. F. E. Emory.—I wish to say a word or two as to this system. Last summer a gentleman who had a large contract to build a lock and dam on a Western river told me he was obliged to give up his contract because he could not get laborers. Laborers there demanded $2 a day, and by laborer was meant a man who could not do anything—a man who had failed in every other calling. All broken-down, worn-out men are there classed as laborers. When a man cannot work at anything else, he thinks he can work as a laborer for the Government or a contractor or coal miner. The reason is that labor is not a profession in this country,

although it should be. We have our trained professional men, but the laborer is the man without a training. He should have a well-developed muscle and sufficient mind to operate that muscle. He must have good food and good clothing, and he must be temperate. He must be a trained man to be a laborer as much as to work in any other calling; and if our State could have furnished the contractor with 300 laborers of this class he would not have had to withdraw his Government contract, and we would have had our locks and dam much sooner. (Laughter and applause.)

Mr. Orosco C. Woolson.—I have been pleased with Mr. Taylor's plan, and several things come to my mind which prompt me to indorse his conclusions. Without going into a discussion of the whole subject I want to express what to me seems of particular value in his plan of subdivided foremanship. In the first place, the sub-foremen must, and would, become experts in their particular departments; hence it follows that the workmen under them would naturally become more proficient as all-round mechanics. This will have greater potency when applied to our apprentices, and for this reason, if for no other, the plan proposed by Mr. Taylor appeals to me. It would not be reasonable to suppose that such a system of sub-foremanship could be profitably applied to every shop, both large and small; yet, in my judgment, an apprentice brought up under such a system would be a better mechanic when the time came for him to take up work as a journeyman.

*Mr. Gantt.**—I do not know that there is much for me to say. I wish to emphasize again, though, one point which I made this morning, and which many people who are here now may not have heard, namely, that the system involves a system of education, and I believe that the lack of trained men can be supplied by this means more quickly than by any other which is now available. (Applause.)

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* Author's closure, under the Rules.

No. 929.*

A SILENT CHAIN GEAR.†

BY J. O. NIXON, PHILADELPHIA, PA.
(Junior Member of the Society.)

1. THE advantages of chain gearing for power transmission have long been recognized by the engineer, and since the introduction of the Ewart Detachable Link-Belt in the early seventies, the use of drive chains has steadily increased, until now many million feet of driving chain are made and sold every year.

2. While the field in which this immense quantity of chain is used is necessarily very large, it is only a small part of the whole realm of power transmission. The reasons why chain gearing has been thus limited in its application are:

First.—The noise heretofore inseparable from all chain gearing.

Second.—The comparatively low speed limits.

Third.—The more or less rapid increase of noise and jar due to the stretch and wear of the chain and the wear of the wheel.

These three defects, inherent in all ordinary chains, are due to the stretch of the chain, by its elasticity and by wear, both internal and external, which make a chain, as soon as it is started up, too large for the sprocket which it was made to fit.

Fig. 148 will possibly make this clearer. The figure shows a driven sprocket wheel and a chain of the ordinary type. This chain, it is assumed, was made to fit the sprockets. However, as soon as the gear was started up, the pitch lengthened so that

*Presented at the New York meeting (December, 1901) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For previous discussions on this and related topics consult *Transactions* as follows:

No. 198, vol. vii., p. 273: "Experiments on the Transmission of Power by Gearing." Wilfred Lewis.

No. 202, vol. vii., p. 347: "Transmission of Power by Belting." Gaetano Lanza.

No. 213, vol. vii., p. 549: "Experiments on Transmission by Belting." Wilfred Lewis.

No. 426, vol. xii., p. 230: "Rope Driving." C. W. Hunt.

this is no longer the case. This lengthening of the pitch, or stretch, is due to the following causes: The pins bed in their bearings, the stress on the chain stretches the metal, which is, of course, elastic, and wear of the pins and of their bearings begins at once and is a constantly increasing factor. Add to this the decrease in root diameter of the sprocket due to wear, and we have the conditions shown in the figure, of a wheel running with a chain which is too big for it. This means that one tooth alone is doing all the work at any given time.

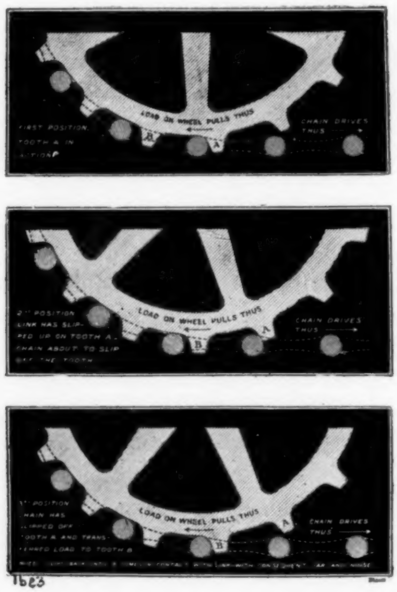


FIG. 148.—ORDINARY CHAIN AND SPROCKET.

3. In the first section of Fig. 148 we have tooth A in action; in the second section the wheel has revolved and the chain is about to slip off tooth A, and in the third section the chain has slipped off, and the wheel has slipped back under the influence of the load, until tooth B comes in contact with the chain. This slipping back of the wheel makes a noise and causes a shock to both chain and wheel. These shocks occur every time a link passes out of mesh and, therefore, at even very moderate speeds, the number per minute is very large. It has been proved by experiment and by practice that this jarring

action is very wasteful of power, and that the amount of power consumed by it increases more rapidly than the speed increases, so that the allowable useful working stress becomes smaller and smaller with increasing speed. This limits the speed at which a chain may be run. Of course this limiting speed varies greatly for various styles of chain and is much higher for a steel roller chain of proper design than for a malleable chain. What has been said above with reference to a driven sprocket applies with equal force to the driver.

4. From the foregoing it will be immediately inferred that the solution of the problem of producing a *high speed* and a *silent* chain gear lies in the production of a wheel and chain which shall always remain a perfect fit each with the other entirely independent of the stretch of the chain. Such a chain gear has been developed by Mr. Hans Renold, of Manchester, England, and has been in wide and successful use in Europe for some five years past. This chain gear consists of a chain composed of links of a peculiar form stamped from the sheet or cut from a drawn bar fastened together by shouldered rivets into a chain of any desired width (Figs. 149–151) running over cut sprocket wheels with teeth of a shape varying with the size of the wheel. It is absolutely silent and may be run at high speeds. It is capable of transmitting any amount of power from the smallest to the greatest.

5. How the Renold chain gear accomplishes its results may be best seen by reference to Fig. 152. It will be noted at once that the chain has contact with the wheel on the faces of the teeth only, and not on the root circle at any time. The flat bearing surfaces of chain and wheel at corresponding angles cause the chain to take the form of a perfect circle at all times, with a pitch diameter corresponding to the pitch of the chain, and not to the pitch of the wheel, as is the case where the bearing is on the root circle. Because of the above, every tooth in mesh is in equal contact with the chain, and remains so whatever the stretch. As any given tooth goes out of contact with the chain there is no slipping back of the chain, for the next, and every other tooth in mesh, is in perfect working contact with it. Thus there is no noise connected with the operation of the chain, and the cause which limits the speed of the ordinary chain gear does not exist. The first section of Fig. 152 shows a new chain on the sprocket; the second section

shows the same chain after having stretched, and illustrates how the chain automatically adjusts itself to the sprocket, remaining always a perfect fit for it; the third section shows the rolling action of the chain as it comes into mesh. There is seen to be no sliding of the chain on the sprocket tooth, which means, of course, minimum of wear and a maximum of efficiency. The

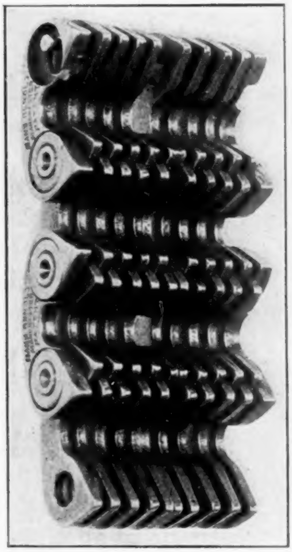


FIG. 149.—STAMPED CHAIN.

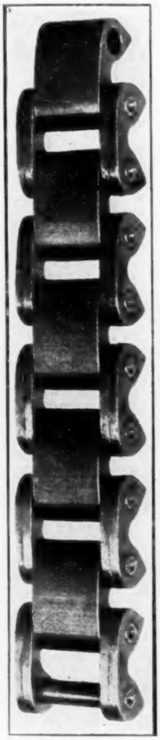


FIG. 150.—BLOCK CHAIN.

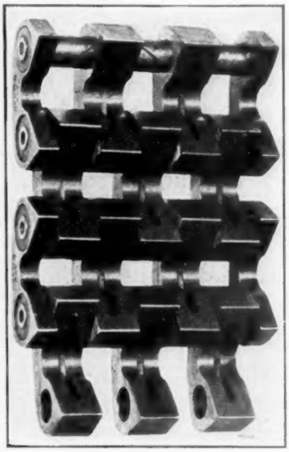


FIG. 151.—MULTIPLE BLOCK CHAIN.

Renold Silent Chain Gear, as Mr. Renold has named this development, is therefore noiseless; it can be run at high speeds; and it retains the originally perfect action until worn out. Another valuable property, which is a corollary of the self-adjusting feature of the chain, is the possibility of running two or more chains side by side on the same wheels. In this way, when large powers are to be transmitted, and the width of chain necessary becomes too great for convenience in manufacture or

in handling, several chains may be used with the perfect assurance that each will bear its proper share of the load. This is in great contrast to the known impossibility of getting two ordinary chains to stretch evenly and so distribute the load between them. As the number of chains becomes greater the difficulty by the old method is more than proportionately increased.

6. The life of a chain is the length of time which it will take to stretch it so much that it ceases to have any bearing whatever on the teeth of the sprocket wheels. A very small bearing will suffice, because the load is divided between all the teeth in mesh.

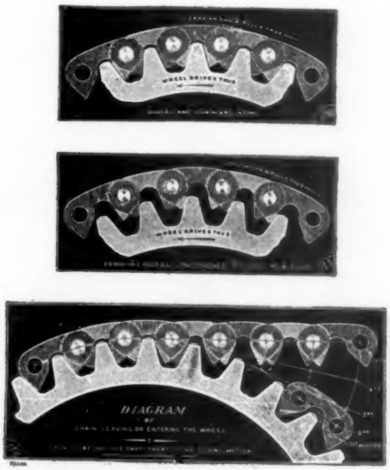


FIG. 152.—SILENT CHAIN AND SPROCKET.

Hence, to prolong the life of the chain, the steel used in its manufacture must be of the very highest grade obtainable, and it must be worked with the utmost accuracy. A steel for the links of high tensile strength allows the use of pins or rivets of large diameter while preserving the tensile strength of the chain as a whole. The large bearing surface so obtained is rendered yet more valuable by the use of hardened pins of high grade material. The washers on the ends of the rivets claim no little attention. They must be small in diameter and not too thick. This necessitates a steel of high tensile strength and elasticity, so that the washer shall grip the rivet end when it is forced over it and still, by its small size, not add to the bulk nor detract from the appearance of the chain.

From the question of material one naturally passes to the allowable limits of error in workmanship. In a general way it may be said that the chain should be as accurate as it is possible to make it. The pitch must be accurate, the holes must be properly located, and the rivets must be neither so short as to bind the links nor so long as to give excessive play.

7. The sprockets used with the silent chain form, of course, an indispensable part of the gear. They must be accurately cut with special cutters and may be of any material. The teeth have straight sides to give a full bearing with the working surfaces of the chain. The angle of the tooth is different for every diameter of sprocket; or, to put it in another way, the angle between the sides of the tooth becomes greater as the number of teeth increases. The limits to the number of teeth that may be

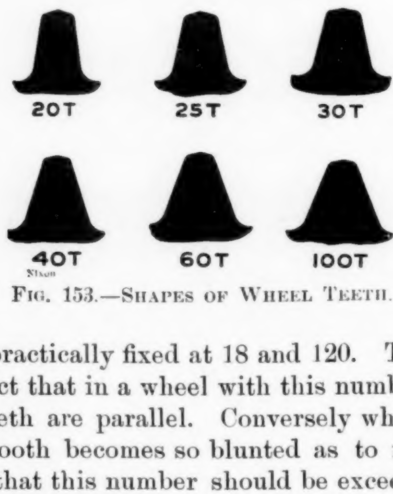


FIG. 153.—SHAPES OF WHEEL TEETH.

employed are practically fixed at 18 and 120. The former limit is set by the fact that in a wheel with this number of teeth, the sides of the teeth are parallel. Conversely when a wheel has 120 teeth, the tooth becomes so blunted as to make slipping a possibility, so that this number should be exceeded only where the load is absolutely uniform.

This variation of the tooth shape is illustrated in Fig. 153, which shows several steps in this gradual change of shape. It will be readily understood that the variation between the shapes shown is a gradual and not a sudden transition. The fact that the load on the sprocket teeth is distributed over all the teeth in mesh obviates the necessity of using a metal of high tensile strength for the sprocket wheels. The fact that there is no sliding of the chain on the sprocket teeth obviates the necessity of using a very hard metal to minimize wear. It is therefore possible to make a strong and durable sprocket wheel of cast iron. Steel,

however, has been used for the small wheel on automobiles, and in other cases where the service was particularly severe. The flanges are put on after the teeth are cut, and are either shrunk on, or rivetted to the wheel.

8. With regard to the practical use of the chain the following points may prove of interest: It is obviously necessary that one wheel of the pair be flanged to prevent the chain running off; it has been found that better action is obtained where the driven wheel is flanged; the chains may be run with the sprockets so close together as to barely clear, or the drive may be of any length up to ten to fourteen feet without supporting idlers and, if such support be used, may be of any length found economical and desirable.

The only factor so far found which serves to limit the speed is the difficulty of keeping the lubricant on the chain at very high speeds. At speeds exceeding 1,350 to 1,400 feet per minute, the oil is thrown off by centrifugal force, but speeds as high as 2,300 feet have been employed successfully by enclosing chain and wheels and running them in oil. The particular case in mind was the transmission of 75 horse-power from the motors to the car axle on the Mono-rail Railway, at the Brussels Exposition. This is the type of road which is soon to be erected between Liverpool and Manchester.

This is by no means the only case where high speeds have been attained by enclosing the gear, but is simply cited as typical. In this connection, however, it may be well to call attention to the fact that the chain speeds being lower than the speeds necessary for belting, allows sprockets of correspondingly smaller diameters for the same angular velocities. The chain thus effects a marked economy of space, not only in the diameter of the wheels, but because of the comparatively long centres absolutely essential with belting. The line of centres may be horizontal, inclined, or vertical, provided that the shafts are parallel, but there are two limitations on vertical drives. The small wheel should not be the upper one, because the weight of the chain crowds it into the sprocket and gives bad action. Some form of tightening device should be provided, either by adjusting the centres, or by an idle roller on the slack side of the chain, so as to prevent the chain, when it stretches, from falling away from the lower sprocket. Both of these troubles may be obviated by inclining the line of centres.

Wherever the chain gear is exposed to dust or grit of any sort, it should be enclosed in a dust-tight casing. In any case, a light metal guard should be provided to prevent anything falling into the gear.

9. The statement was made in the beginning of this paper that the causes which had heretofore limited the use of chain gearing were the speed limit, the noise, and the more or less rapid deterioration of the action of chain and wheels. We have now seen how these three defects have been eliminated in the Renold Silent Chain Gear, and this question naturally arises: "To what is the silent chain gear especially applicable, and how has it proved its usefulness in the past?" An answer to the latter half of this question will also be the best answer to the first half.

It is hard to name a branch of the mechanical world in which the silent chain has not made a permanent and honored place for itself. It has been used on machine tools in numberless ways; it forms an integral part of many special machines; it drives shallow-draught gunboats on the Nile, and heavy gun lathes in Sheffield. Engine governors are driven by it, and the motors whose power is transmitted through this medium are hundreds in number and of all sizes, from the smallest to the largest. Builders of automobiles of all types have found that the silent chain offers a solution of their difficulties, and it is in use to-day on hundreds of cars, from the light three-wheeled pleasure carriage to the heavy steam truck. In our own country, Messrs. Brown & Sharpe have been using this chain for some time for driving the spindles and feeds on their machines. The new factory of the Natural Food Company, at Niagara Falls, is driven throughout by silent chain. Here the service is severe because of the sudden start and quick acceleration, under load, of the induction motors used. The drives vary in size from 1 to 40 horse-power. These are only notable instances, for already the chain is in use in many varieties of service on this side of the water. Figs. 154–156 show applications of the chain. The data as to these transmissions are given under the figures themselves.

10. To sum up.

The Renold Silent Chain Gear possesses, in common with all chain gears, these advantages:

(1) A positive speed ratio (no slip).

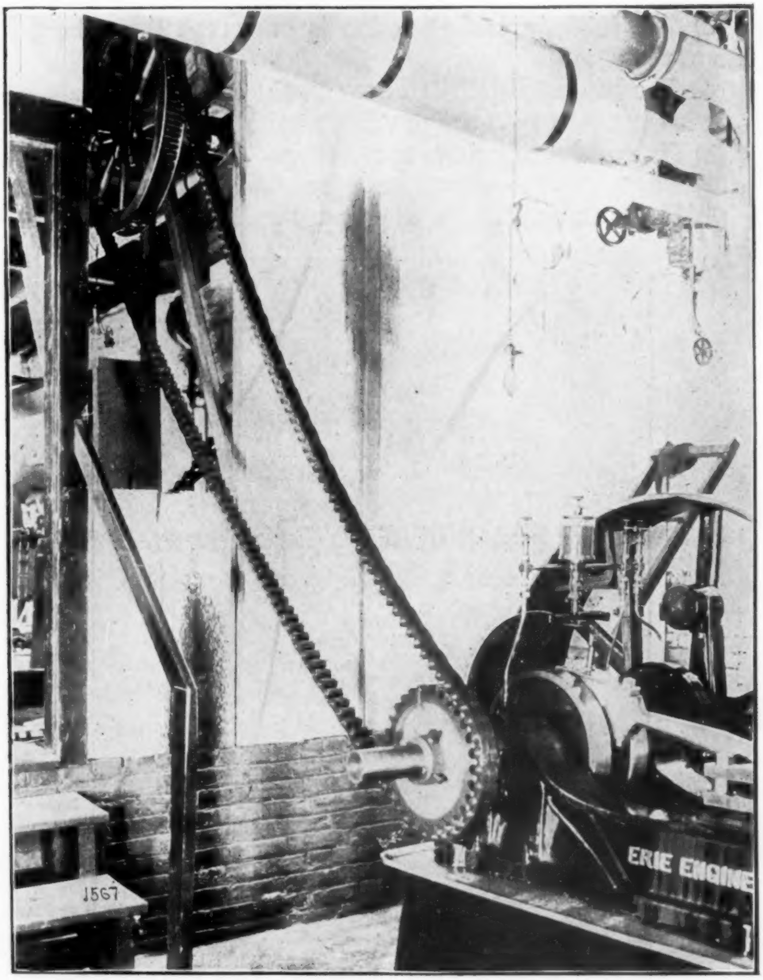


FIG. 154.—CHAIN DRIVE, 25 HORSE-POWER ENGINE TO LINE SHAFT, CHAIN SPEED 900 FEET PER MINUTE.

(2) No tension in the slack side of the chain and, therefore, a minimized loss in journal friction.

(3) Adaptability to short centres or to long centres.

(4) Adaptability to hot or damp situations.

In addition to these it possesses the following unique advantages:

(1) It is silent.

(2) It may be run at high speeds.

(3) The initially perfect action is preserved throughout the life of the chain.

(4) The load is distributed over all the teeth in mesh.

It is superior to leather or rubber belts because—

(1) It provides a positive speed ratio.

(2) There is a minimum loss in journal friction.

(3) It can be used in hot or damp situations.

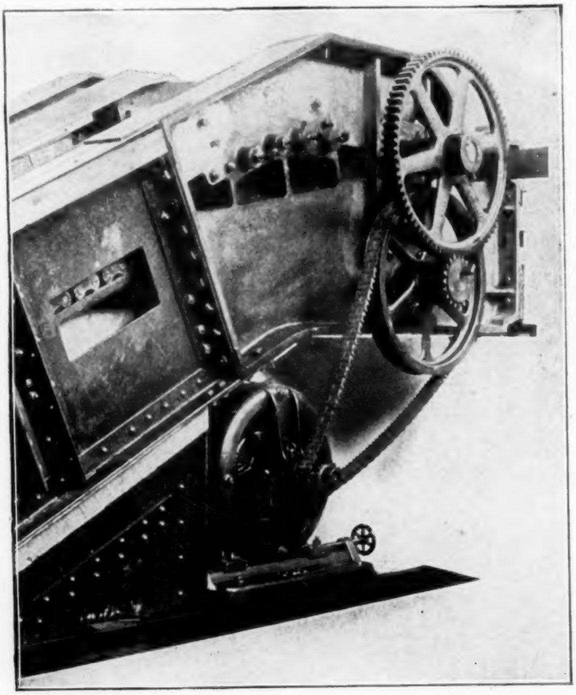


FIG. 155.—10 HORSE-POWER DRIVE ON STAIR LIFT, CHAIN SPEED 1,070 FEET PER MINUTE.

(4) It can be used on short centres without a troublesome and wasteful idler.

It is superior to spur gearing because—

(1) It is noiseless.

(2) It does not require fixed centres.

(3) It does not require short centres

(4) There is no sliding friction on the teeth, hence it is more efficient.

(5) It is smoother in action and generally more durable.

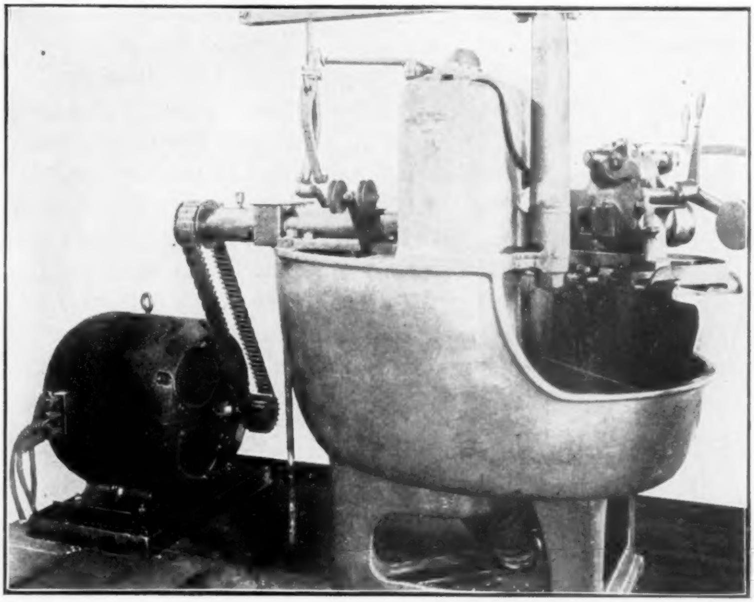


FIG. 156.—7 HORSE-POWER CHAIN DRIVE ON SELLERS GRINDER, CHAIN SPEED 1,000 TO 1,800 FEET PER MINUTE.

The writer believes that no one who has given the subject even casual thought will dispute the assertion that the development of the Renold Silent Chain Gear marks an era in the history of power transmission.

DISCUSSION.

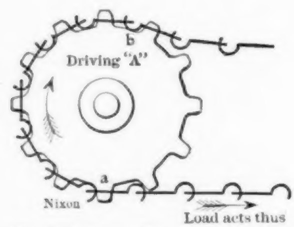
Mr. Harrington Emerson.—I have been following this chain for some time with great interest, and I think that everything which has been claimed for it is true, but it seems to me that in this paper perhaps the old chain is somewhat slandered under paragraph 3. If you will look at the diagram, Fig. 148, and assume that the wheel, and not the chain, is the driver, you will find that there is no slipping action whatever; and if the chain is made so that the link engages at the lower part of the wheel instead of the top, the slipping action which is described and the consequent jarring are eliminated, and the chain can stretch and stretch until it reaches a point where it is no longer in mesh. Chains made to gear in that way will last very much longer, al-

though only one tooth engages, and they wear less than if made in the ordinary way.

Mr. George I. Rockwood.—I would like to ask the author of the paper why this chain solves the automobile-chain problem ?

Mr. Nixon.—The peculiar adaptability of the silent chain to automobile service arises from the fact that it compensates for the stretch by riding out on the wheel, which means that there will be perfect action throughout the life of the chain. Also, the continued jarring, which tends to stretch the chain and which absorbs a large amount of power, is eliminated. We have made a great many experiments on this subject and proved how great this power loss is. The silent chain, because it remains a perfect fit, is more efficient and less liable to jump.

Now, with regard to the point raised by Mr. Emerson: I be-



Wheel pitch smaller than chain pitch.
Entering tooth "a" does all the work.

Fig. 157.

lieve that the gentleman is correct to a certain extent. Just what he describes does happen with a driving-wheel when it is smaller in pitch than the chain. Referring to Fig. 157, which represents the driving-wheel with the wheel pitch smaller than the chain pitch, we have the entering tooth *a* doing the work as stated by Mr. Emerson. This is exactly what happens in practice, because wheels made to fit the chain soon become relatively small, owing to the stretch of the chain.

Now, it is perfectly feasible to do this on the driving-wheel because there is tension in the chain as it comes on the wheel which will force the chain to its seat. In doing so, however, it imparts a jar to the chain, which is one cause of the trembling in the tight side of the ordinary chain.

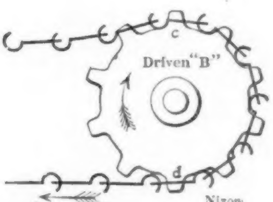
If, now, we consider the driven wheel, Fig. 158, the conditions are reversed. Here the wheel pitch must be larger than the chain

pitch to make the entering tooth do the work. As soon, however, as this is attempted, the chain rides the sprockets, because there is no tension in the chain as it comes to the driven wheel to force the chain to a seat.

While Mr. Emerson is correct in saying that the entering tooth may be made to do the work on the driver, still the sum total of experience in chain driving is that the best, most efficient, and most durable gear of the *ordinary* type is obtained when the wheels are so constructed that the releasing tooth does the work on both wheels.

All this discussion on the means of minimizing the objectionable features of old types simply emphasizes the good points of the new silent chain.

Mr. Rockwood.—Speaking about why automobile chains jump



Wheel pitch larger than chain pitch.
Entering tooth "c" does all the work.

FIG. 158.

off their sprockets (and the subject of automobiles is liable to lead us into the wilds, but I will try to confine myself to automobile chains), I found for myself, after extended looking for the trouble, why the chain did jump so often. It was because the compensating-gear sprocket, which floats by means of its pinions on the two bevel gears on the abutting ends of the two rear shafts, wabbles when the yoke which unites the bearings of the two rear shafts spreads under the weight of the carriage and the pull of the chain. If you can prevent that wabbling, it is a mighty poor job of a chain that will not stay on, even when slack. I have seen Baldwin chains very slack indeed with 12 horse-power on them that never jumped; never knew of a case of those big chains jumping, because the yoke was made heavy enough in those carriages to hold the bevel gears in their original positions. In reality, the trouble with my first carriage was in the wabbling of the

rear sprocket. By preventing this I overcame the tendency of my chain to jump.

*Mr. Nixon.**—With reference to Mr. Rockwood's statement I would say that bad automobile construction is not properly a part of this discussion. The point which I attempted to make was that with the same amount of stretch, the silent chain would be a fit for the sprocket, while the roller chain would tend to climb the sprockets and jump. Of course, defects such as he mentions are a serious contributory source of trouble , but the inherent and recognized type defects of the ordinary chain remain, however well the sprockets may be supported.

* Author's closure, under the Rules.

No. 930.*

THE "POTTER" MESH SEPARATOR AND SUPERHEATER.

BY FREDERICK A. SCHEFFLER, NEW YORK.

(Member of the Society.)

1. VARIOUS designs of dry pipes † have been made, all of them with a view of accomplishing the same result, namely, that of affording a receptacle for the steam passing out of the boiler, and so devised that steam only, and no water, should pass through the dry pipe. The very fact that these various forms of dry pipes (sometimes deflectors were used) have been changed in design, and also that in many instances the dry pipe has been abandoned for another device equally deceptive, without eliminating the difficulty, is proof that none of the old methods were satisfactory under all circumstances, and that a form of dry pipe which might be suitable in one case would not apply in another equally well.

2. I have no doubt that many members in reading or discussing this paper can recall their experience with priming or foaming boilers, and what they did to prevent disastrous accidents from occurring to their engines and other machinery. This is an experience which many of us have had.

It is a well-known fact that under certain operating conditions even the best designed boiler is likely to "throw water," or prime or foam badly. This may be due to various causes, which we have not the time to discuss now, and frequently is not due to improper construction of the boiler.

3. The "Potter" mesh separator is designed to prevent the trouble above referred to from occurring within the boiler itself,

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* Presented at the New York meeting (December, 1901) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For previous discussions on this topic consult *Transactions* as follows:

No. 618, vol. xvi., p. 137: "Description of Improved Forms of Steam Separator, Steam Jacket, and Reheater." Chas. T. Porter.

No. 810, vol. xx., p. 485: "Test of a Steam Separator." F. L. Emory.

and while boilers equipped with the apparatus may prime for various reasons, the separator makes it impossible for the boiler to "throw water." The device is placed in the steam space of the boiler, and is connected in a manner similar to a dry pipe, or it can be connected to the end of the dry pipe, and the holes in the latter stopped up.

The construction of the separator is shown in the half-tone herewith (Fig. 159), and also in longitudinal sectional elevation

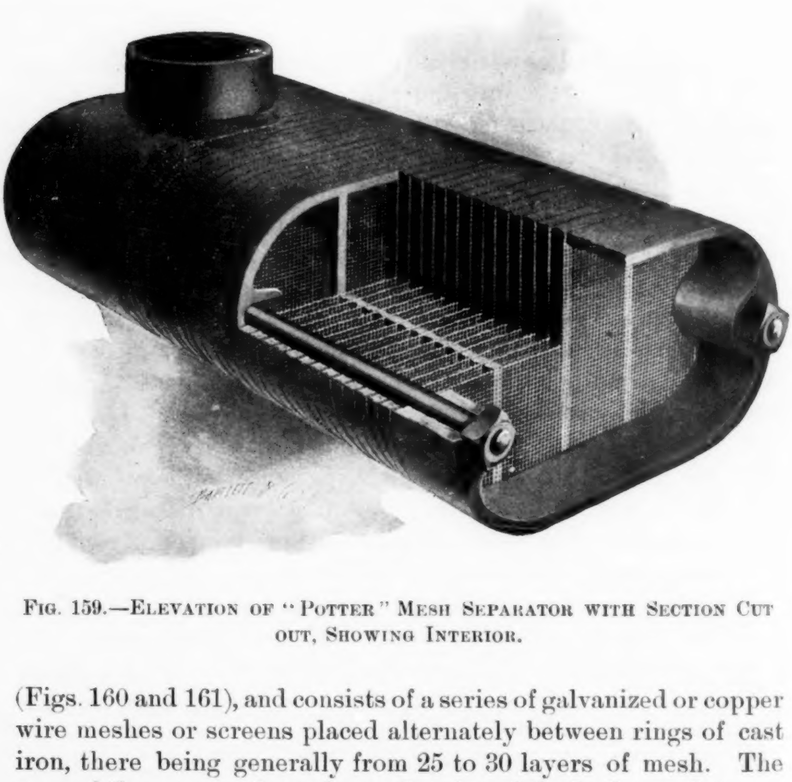

FIG. 159.—ELEVATION OF "POTTER" MESH SEPARATOR WITH SECTION CUT OUT, SHOWING INTERIOR.

(Figs. 160 and 161), and consists of a series of galvanized or copper wire meshes or screens placed alternately between rings of cast iron, there being generally from 25 to 30 layers of mesh. The area of the screens depends on the size of the boiler outlet.

After considerable interesting experimental work, involving many other designs, more or less complicated, the above construction is found to fulfil all conditions of priming, over-saturated steam, etc., and delivers at the boiler outlet *practically* dry steam.

It has also been found by careful experiment that, given any

boiler from which steam is delivered at any particular range of moisture (with or without "dry pipe"), the introduction of the mesh separator in the same boiler will change the quality of the

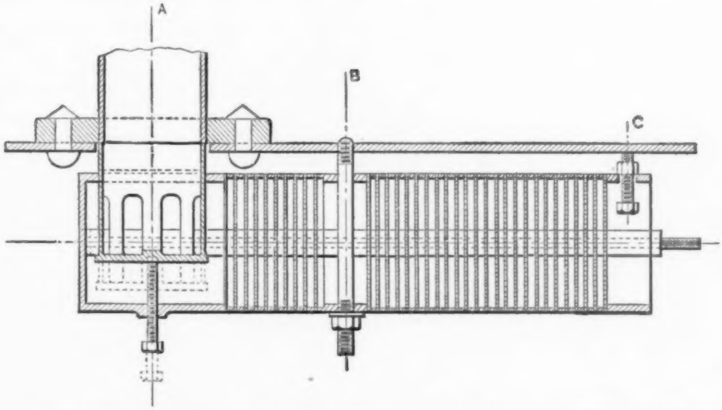

FIG. 160.—"POTTER" MESH SEPARATOR—LONGITUDINAL SECTION.

steam by from 25 to 75 per cent. (making it drier), and at the same time stop any priming which may have been present.

The theory on which the action of this separator is based is, as may already have been surmised, that the small globules of

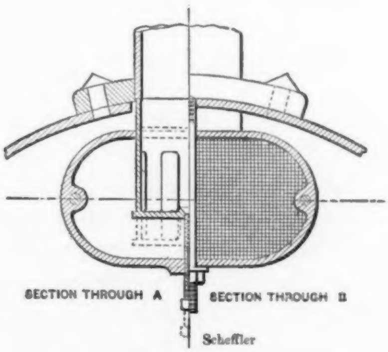

FIG. 161.—CROSS SECTION.

moisture contained in the steam are broken up by the first piece of mesh, and this action is continued through each successive layer of mesh until it is so completely atomized upon reaching the outlet chamber, or header, that it flashes into dry steam upon

the addition of a small amount of heat, which is obtained by the wire-drawing due to the steam and water passing through the screens. The reduction of pressure is about 1 per cent., and the temperature of the steam is increased proportionately.

The separator is designed so that it can be placed in any type of boiler which is equipped with a manhole of the usual size (11 inches by 15 inches), and is held in position by one or more studs screwed into the shell of the boiler. The connection between the outlet of the separator and boiler outlet is not necessarily steam tight, nor are the joints between the faces of the rings and wire mesh steam tight, as these openings are so small

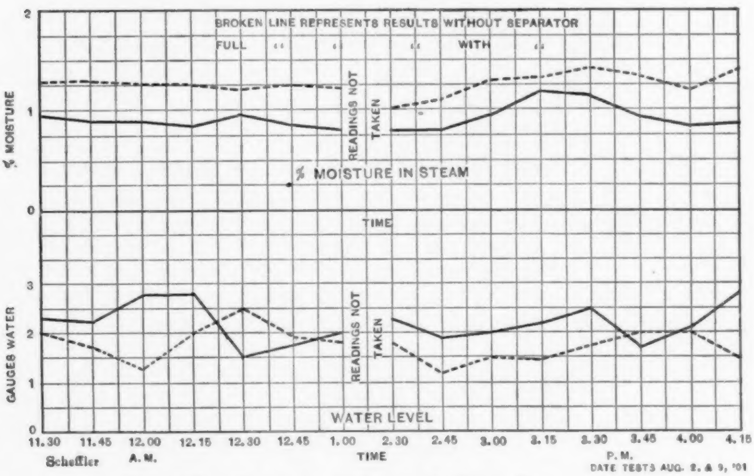

FIG. 162.—TESTS OF "POTTER" MESH SEPARATOR.

that any steam which leaks through such spaces is slightly wire-drawn with the same result which occurs to the steam passing directly through the mesh of the separator. These small openings on the lower part of the separator also provide the means whereby the entrained water returns to the boiler as it trickles down the successive layers of wire mesh.

4. Tests recently made by the writer in a 3,000 horse-power electric plant with and without the separator are graphically shown in Fig. 162, together with water-level readings taken simultaneously with the calorimeter readings. These readings were taken every minute for five minutes over several hours' duration, at ten-minute intervals, and in plotting the curve it will be

noted that the average readings for each five minutes were used to give the ordinates.

A Carpenter throttling calorimeter was used, as the readings at no time exceeded 2½ per cent. of moisture.

5. In this particular case the tests show that the steam issuing from the boilers contained 37½ per cent. more moisture when the separators were not used than was the case when they were used, and this, notwithstanding the fact that the water level in the latter instance averaged materially higher than in the former. Before these separators were installed, this particular plant was frequently troubled with water in the engines, but this difficulty has entirely disappeared; so that, as heretofore stated, the separators prevent the water from leaving the boiler, besides supplying a higher quality of steam.

This test was made on boilers which, as the curve shows, would ordinarily furnish a very fair quality of steam, and the test casts no reflection on the makers of the boilers. If, however, by applying the improvement in "dry pipe" construction, the possibility is assured of keeping the water in the boiler, and at the same time increase materially the quality of the steam *at the boiler outlet*, then the plant as a whole is improved in efficiency. There will be far less condensation to take care of in such installations between the boilers and the engines, and there will also be eliminated the likelihood of damaged engines, providing the condensation is properly looked after.

DISCUSSION.

Mr. J. J. de Kinder.—My experience with boilers covers a period of over forty years, and the best form of separator or dry pipe for use inside a boiler is, in my opinion, no dry pipe at all. Notwithstanding the fact that many engineers recommend the use of dry pipes, I have invariably found it beneficial to throw them out. I cannot agree with Mr. Scheffler that it is a well-known fact that under certain operating conditions, even the best designed boiler is likely to throw water, or prime or foam badly. A properly designed boiler, properly piped and handled, will not prime or foam badly. I notice that Mr. Scheffler, in paragraph 3 of the pamphlet, says, "After considerable interesting experimental work involving many other designs, etc., the above construction," referring to the "Potter" mesh separator, "is found to fulfil all

conditions, etc., and delivers at the boiler outlet *practically* dry steam."

As a matter of fact, I find that most water-tube boilers deliver practically dry steam if they are properly handled, and I can hardly realize that Mr. Scheffler is in earnest when he writes those ten lines of paragraph 3.

It would be very interesting to know just what kind of experimental work has been done with the separator referred to, and until full and complete data in this regard are given I consider the claims made absolutely absurd.

Mr. A. C. Wood.—The tests reported in Mr. Scheffler's paper are incomplete and consequently not conclusive. The quantity of steam passing through the dry pipe during the whole run, or during each period of fifteen minutes, is not stated; the steam pressure is not noted; the kind of collector nipples used and the point and manner of attachment of the calorimeter are not described; the conclusions as to the capabilities and value of the Potter separator are based entirely upon the indications of the throttling calorimeter, no means having been used for measuring absolutely or even with any approximate certainty the quantity of steam supplied by the boilers. Every one who has done much experimenting with calorimeters and various forms of collector nipples understands the uncertainty and unreliability of this means of obtaining results. The calorimeter itself is all right, but collector nipples can be made to give almost any result imaginable.

Admitting, for the sake of argument, that the results obtained with the calorimeter are correct, the diagram is rather too small to admit of accurate deductions, but very good approximations can be made. There is no direct relation of cause and effect apparent in the lines. For instance, in the lines "without separator" six periods show moisture decreasing as the water line falls; ten periods show moisture increasing as water line falls; four periods show moisture increasing as water line rises; and six periods show moisture decreasing as water line rises. Twice the moisture is at a minimum when the water line shows a peak or maximum, but not once do peaks in both occur simultaneously.

With the separator, six periods show moisture decreasing with falling water line; two, moisture increasing with falling water line; six, moisture increasing with rising water line; twelve, moisture decreasing with rising water line. Again, the moisture

is twice at a minimum when water line shows a peak; once, the moisture shows a peak when water line is low; not once, however, do peaks occur simultaneously. It would seem more reasonable to conclude that the increase or decrease in entrainment is due to sudden variations in the load, and, consequently, in the activity of ebullition, rather than to changes in the water line. It will be noted that the entrainment gradually decreased from 11.30 A.M. to 1.00 P.M.; and from 2.30 P.M. the moisture gradually increased, reaching a maximum about 3.15 or 3.30 o'clock in the afternoon (on both days), and thereafter decreased until 4.00 P.M., when a period of increased entrainment again began.

The average entrainment without the separator is about 1.25 per cent., and with it about 0.91 of 1 per cent. That is to say, without the Potter separator each 1,000 pounds steam passing from the boiler contained 12½ pounds of water, and with the separator 9.1 pounds of water. Mr. Scheffler tells us that this increase in dryness was obtained with only 1 per cent. loss in pressure; in fact, that 1 per cent. represents the loss under the general conditions of practice.

If the "small amount of heat" to effect this drying of the steam, *i.e.*, the evaporation of 3.4 pounds of water be obtained by wire-drawing, this heat must then be abstracted from the whole amount present in the steam as it is made and passes through the separator. Let us consider two cases, one with steam pressure at 200 pounds, the other at 100 pounds. The 1,000 pounds of steam are actually composed of 987.5 pounds steam and 12.5 pounds water, which latter, no doubt, has the heat due to the pressure. The total heat of the steam is, respectively, 1,200.2 and 1,184.5 heat units, and of the water 360.9 and 308.6 heat units per pound. We have, therefore, in 1,000 pounds of the moist steam, respectively, 1,189,-709 and 1,173,551 heat units.

If by a further refinement of this wire-drawing action we could evaporate all the entrained water, we would have heat enough present to give us 1,000 pounds of dry steam at, respectively, 129 pounds and 54.5 pounds pressure; *i.e.*, the conversion by wire-drawing would cost us a loss of 71 pounds pressure for steam at 200 pounds and of 45.5 pounds for steam at 100 pounds pressure.

But the case as presented only shows 3.4 pounds of water wire-drawn into steam; *i.e.*, 9.1 pounds remain entrained in the 1,000 pounds of steam. These 9.1 pounds contain, respectively, 3,284 and 2,808 heat units which we must deduct from the total store

for each pressure, leaving us, respectively, 1,186,425 and 1,170,743 heat units for the remaining 990.9 pounds of dry steam. This dry steam then has 1,197.3 and 1,181.5 heat units at the resultant pressures corresponding to 180 and 86 pounds. An allowance must, of course, be made for the reduced heat of the liquid, which, however, only brings these pressures up to 181 pounds and 86½ pounds. At the higher pressure, therefore, the loss is 19 pounds; at the lower, 13½ pounds; or, respectively, 9.5 and 13.5 per cent. instead of 1 per cent.

But the statement is made that 25 per cent. to 75 per cent. of the moisture can be eliminated by this separator. Let us try results at 50 per cent. of the 12.5 pounds which we find from the chart; *i.e.*, on 6¼ pounds of water. We would then have 6¼ pounds entrained water remaining in 1,000 pounds of steam supplied from the boiler, which water would contain 2,256 and 1,929 heat units at the two assumed pressures, respectively. Deducting, as before, these quantities from the total store of heat in 1,000 pounds of moist steam, we have, respectively, 1,187,453 and 1,171,622 heat units as the heat contained in the 993.5 pounds of dry steam after wire-drawing through the separator; or, say 1,195.2 and 1,179.3 heat units per pound, representing dry steam at 166 and 76 pounds pressure after making allowances for heat and liquid. The losses in pressure to reduce the percentage of moisture from 1¼ per cent. to ⅝ of 1 per cent would, therefore, be 34 pounds and 24 pounds, or 17 and 24 per cent., respectively, for steam at 200 and 100 pounds boiler pressure.

The conclusions are inevitable:

First. The higher the pressure in the boiler the less will be the percentage loss in pressure to affect the drying or superheating of the steam.

Second. To effect even a small reduction in the entrainment, the loss in pressure would be too serious to be countenanced and would lead to awkward complications. This is no fault of the separator, but one of the inherent conditions of the problem.

Third. Sudden demands for steam could not be met, as the pressure in the steam main must fall rapidly, and the more effective the separator the surer the result.

Prof. John H. Barr.—It is to be regretted that the author of this paper does not give us more data of tests conducted with the device described in his paper. It is possible that tests on boilers which prime considerably more than those reported might

make a much better showing; but the results reported in this paper do not indicate a very remarkable performance, and there seems to be little justification for designating this device as a superheater.

It is stated that this separator is based upon the theory "that the small globules of moisture contained in the steam are broken up by the first mesh, and this action is continued through each successive layer of mesh until it is completely atomized upon reaching the outlet chamber, or header; that it flashes into dry steam upon the addition of a small amount of heat, which is obtained by wire-drawing due to the steam and water passing through the screens. The reduction of pressure is about 1 per cent., and the temperature of the steam is increased proportionately." It seems probable that much of the water broken up by striking the screens will be carried on by the current of steam, simply as a larger number of smaller globules, before it can trickle down the screen surface to the drips at the bottom of the chamber. However finely divided, all of the original moisture, except the portion which escapes at the bottom or is evaporated by heat, remains in the current *as water*.

The improvement in the quality of the steam by wire-drawing equivalent to a reduction of pressure of 1 per cent. is very small. If the steam pressure in the boiler is 150 pounds per square inch, a reduction by wire-drawing of 1 per cent., or of 1.5 pounds per square inch of pressure, can only evaporate about .035 of 1 per cent.; a quantity too small to be determined by observation. Furthermore, the method is wasteful, so far as it goes. Any superheating, if accomplished at all, would be at the expense of an excessive reduction of pressure; hence of considerable loss of available energy at the engines. The temperature of the steam is decreased, rather than increased, by wire drawing.

It is stated that the introduction of the mesh separator will change the quality of the steam by from 25 to 75 per cent. The graphical log of the tests shows about 1.25 per cent. of moisture without the separator, and about $\frac{7}{8}$ of 1 per cent. with the device; or about .7 as much moisture with as without the device. This is understood to correspond to an improvement in quality of about 30 per cent., according to the above mentioned peculiar manner of expressing the performance of this separator. The ordinary standard of quality would give the improvement as $\frac{3}{8}$ of 1 per cent.; since the quality without the device is 98.75, and

with the device it is 99.125 per cent. The amount of moisture removed from the steam divided by the amount presumably delivered to the separator by the boiler is .30, or the efficiency of the device is 30 per cent. No doubt, the efficiency of this separator might be better with steam containing more initial moisture; because the best that any purely mechanical action can accomplish is to deliver the steam practically dry. The thermal effect due to wire-drawing may completely dry the steam, or possibly superheat it, but only by delivering it at a pressure lower than that of the initially wet steam. The relation between the drying or the superheating and the loss in pressure is perfectly definite, and cannot be effected by any peculiar structure of the throttling device. The use of an extremely small steam pipe is one way to secure this result.

Tests made by Professor Carpenter on other separators, several years since, showed efficiencies of about 45 per cent. with steam initially containing 2 per cent. of moisture. With 13 per cent. of initial moisture, one separator delivered steam having only 1.2 per cent. moisture; or, according to the standard used by Mr. Scheffler, the "quality" was improved 1,100 per cent. Professor Carpenter's result of 45 per cent. efficiency with 2 per cent. initial moisture corresponds to .9 of 1 per cent. final moisture. The action of the "Potter" separator in delivering steam with $\frac{7}{8}$ of 1 per cent. moisture from steam initially containing 1.25 per cent., constitutes a performance, I should judge, not very much better or worse than that observed by Professor Carpenter with 2 per cent. initial moisture. However, with only about 1 per cent. of moisture to be removed, the best of separators cannot accomplish a great saving, and the merits of the device under consideration would be best brought out by tests conducted under different conditions.

It seems probable, as claimed, that the "Potter" mesh separator may prevent throwing of water in large masses, and it may be very effective for this purpose if conditions are such that this action is apt to occur. The proper position for a separator which is installed to eliminate *diffused* moisture would seem to be near the engine, rather than inside of the boiler, for when placed at the engine end of the steam pipe it can remove moisture resulting from condensation in the pipe as well as that due to priming of the boiler.

Mr. Daniel Ashworth.—I have very little to say upon this

paper. I think Mr. de Kinder has used almost the same phraseology in which I would express my ideas.

I maintain this point, and having had experience with a large number of boilers in this special line of work, I have almost made it a cardinal point in direct contradistinction to this sentence that the best designed boiler is likely to "throw water," or prime or foam badly. I take issue upon that claim right squarely. A well-designed boiler with properly proportioned steam space will not prime or throw water badly. I am, from my experience, compelled to say that the placing of any attachment within a boiler is radically wrong. We have enough in the boiler without placing within it a complication, or a piece of mechanism, or a trap, or any other device. For what it has to do the boiler is sufficient as it stands, if a well-designed boiler. Anything outside of that to accomplish or eliminate any factors that may be developed, we want placed outside.

Therefore, I wish to say that a boiler, properly designed for the specific work for which it is made, will not prime, or throw water. About this claim in paragraph 4 that the priming at no time exceeded $2\frac{1}{2}$ per cent., well, my dear friend is very modest in his claims; in the legion of tests which I have made it is a long time since I have met with $2\frac{1}{2}$ per cent. of moisture, and if my report contained that I would make a note that the moisture was excessive and not considered first class.

Prof. D. S. Jacobus.—Mr. Scheffler has been unfortunate in presenting a theory for the action of the separator described in his paper which will not apply where the amount of water is as great as that usually met with in the priming of boilers, and he has also been misled by tests which do not prove what he intended they should. The title of his paper is also an unfortunate one, as the apparatus which he describes cannot superheat the steam to any extent unless there is an excessive loss of pressure, and it should be classed simply as a separator, and not as a separator and superheater.

I feel that Professor Barr specified what may be the true function of the separator when he said that it seems probable that the "Potter" mesh separator may prevent the throwing of water in large masses, and I wish to add that should this be so, the separator would be efficient for all ordinary cases of priming, because, ordinarily, the water passing from a boiler along with the steam is thrown from the boiler intermittently, and where the priming

might give trouble it is carried with the steam in comparatively large masses.

In my experience in determining the quality of the steam leaving boilers, I have not met a case where, should there be priming, the amount was uniform, or approximately so. I have obtained results with calorimeters which indicated an approximately uniform amount of priming, but either this disappeared on making the proper corrections for the radiation and the steam was found to be dry, or it was found that moisture was blown from some surface so as to be sprayed on the calorimeter nozzle. Where priming has occurred in boilers in my tests the readings of the calorimeter would vary greatly, the calorimeter during certain intervals indicating considerable moisture and at other times dry steam, which shows that where there is priming the steam carries masses of water intermittently from the boiler, and that it does not carry the water uniformly in the form of mist. This refers to the ordinary priming of a boiler such as a separator of good construction will handle when placed on the steam main.

There is another and more severe class of priming where the water appears to foam up in the boiler and to be carried in a foaming condition from the boiler. This class of priming occurs but seldom, and when it does occur is of such a severe character as to call for special action on the part of the engineer and fireman. It is questionable whether any of the ordinary separators will be efficient when this class of priming occurs.

For ordinary cases of priming, where, as I have explained, the water is thrown from the boiler at intervals along with the steam, it is possible that the "Potter" mesh separator may be efficient through checking the velocity of the mass of water, conducting it by a clinging action along the surface of the various screens to the bottom of the separator, and finally back to the boiler.

Statements have been made by previous speakers that properly designed boilers, properly piped and handled, will not prime or foam badly. That is true in a certain sense; nevertheless, I have met cases where priming occurred in well-set standard types, such as horizontal tubular boilers, and where the plants were in charge of capable engineers.

The statement has also been made that one who has done much experimenting with calorimeters and various forms of collector nozzles understands the uncertainty and the unreliability of the results. This is so, if by results is meant the exact percentage of

moisture in the steam. It is impossible, as I have claimed many times before this, to accurately glean an average sample of steam from a steam main by means of the usual perforated collecting nozzle. A calorimeter may be made to indicate the correct amount of moisture in the steam passing through it, but we cannot make sure that the steam and water passing through it is a correct average of all the steam and water flowing through the main. We can show with a throttling calorimeter in connection with its collecting nozzle whether the steam passing through the main is dry or wet, but if wet we cannot determine the exact amount of moisture in the total mass of steam.

The limit of accuracy of the throttling calorimeter in connection with its collecting nozzle does not warrant the comparison which Mr. Scheffler has made of the results of his two sets of tests. As he has said nothing about making corrections for radiation, and for any error in the reading of the calorimeter thermometer, and as the amount of priming indicated by his tests is quite uniform, I think it probable that if such corrections had been made the average results of each of his two tests would have indicated dry steam. In using calorimeters where the steam is dry and where there are variations in the steam pressure, the percentage of priming indicated by each separate set of readings will vary, those for increasing being higher than those for decreasing pressures. This action probably caused the variations found in Mr. Scheffler's tests. The percentage of priming should not be compared simply with the water levels, as Mr. Wood has done.

The third conclusion drawn by Mr. Wood, that sudden demands for steam could not be met with the "Potter" mesh separator, may be a point in its favor; for, as is well known, severe cases of priming may be caused by a sudden drain of steam from a boiler.

*Mr. Scheffler.**—It is interesting to note that whatever criticisms may have been made as to the *theory* on which this separator does its work, none of the parties partaking in the discussion denies the fact that it does or can prevent water from leaving the boiler in case of priming or foaming, and this is really the pith of the whole matter and the prime reason for the existence of this separator, as I understand it. Whether the benefit is derived mechanically or by wire-drawing, it is still a theoretical question as to just how the work is done.

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* **Author's closure, under the Rules.**

Mr. de Kinder is to be congratulated if in all his varied experience he has had no trouble with "properly designed boilers." He is one of a thousand if he has had the fortune to miss such an opportunity to show to what extremes he would resort in order to prevent priming in such a boiler; for such cases *do* occur, and my testimony can be substantiated by hundreds of the best consulting and mechanical engineers in this country. Personally, I have known of two boilers, both properly designed and exactly similar in all respects, and apparently operated under the same conditions; but one would "throw water," and the other would not. The "personal equation" represented by the fireman has a great deal to do with such matters, no doubt, and the best boiler may give trouble with such an element to contend with. I maintain that it is better to equip the boiler in such a way that, in case of careless handling, bad water, or any other causes which make boilers prime or give wet steam, it will be impossible for the machinery operated by the boiler to be damaged.

The above remarks will also apply to Mr. Ashworth's discussion; but I will call his attention to a statement made by Mr. Wm. Kent and others at the New York meeting, 1895, that commercially dry steam contains about 3 per cent. of moisture. (See Volume XVII., *Transactions*, American Society of Mechanical Engineers, page 194.)

Referring to Mr. A. C. Wood's discussion, I would state that the reduction in steam pressure, as calculated by him, due to the wire-drawing, is prevented by the fact that the opening or area in each wire screen is considerably larger than the area of the steam-pipe outlet.

The name "superheater" was given by the engineer who designed this separator principally to distinguish it from the ordinary steam-pipe line separators, from which it is totally different in operation, construction, and location. When a boiler primes or "throws water," no line separator as now designed can take care of the water fast enough to prevent damage to the machinery.

With reference to the discussion by Messrs. Wood, Barr, and Jacobus, I would say, that while I referred in my paper to the superheating effect produced by the separator, in practice very little is claimed on this point. Mr. Wood, in the third paragraph of his conclusion, and Professor Jacobus, in his criticism of the same, between them give the real cause for the effectiveness of

the separator, only it should be remembered that the action referred to takes place not only when the boiler is suddenly called upon for more power, but at the commencement of every stroke of the piston. Professor Barr, also, in his conclusion, says that the separators may prevent the throwing of large masses of water. This I know to be the fact after considerable experience with these separators. It is the chief claim made for the separator, and gives a positive assurance against accident. Professor Barr, in the latter part of his conclusion, suggests that the right place for a separator is near the engine, in order to intercept the condensation in the piping.

I would point out that, should a boiler prime, the water thus passed through the steam pipe abstracts heat from the steam and causes a further precipitation of water. With *initially* dry steam the condensation in a properly covered pipe is practically zero.

PAPERS

OF THE

BOSTON MEETING

(XLVth)

MAY 27th TO MAY 30th, 1902.

No. 931.

PROCEEDINGS

OF THE

BOSTON MEETING

(XLVth)

OF THE

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

May 27th to 30th, 1902.

FRANCIS H. BOYER, *Chairman of Local Committee.*
ROBT. S. HALE, *Secretary* " "
C. J. H. WOODBURY, *Treasurer* " "
GAETANO LANZA, *Chairman Sub-Committee on Meetings.*
WM. LEE CHURCH, " " " *Entertainment.*
W. W. BIRD, " " " *Finance.*
GEO. H. STODDARD, " " " *Excursions.*
MRS. F. H. BOYER, *Chairman Ladies' Reception Committee.*

THE members of the Society, resident in Boston and the eastern part of Massachusetts, had been for some months in active preparation for the holding of the Spring Meeting of 1902 in the city of Boston.

A very large committee composed of members of the Society in and around Boston had been early formed, and they had made active preparations for the reception of the Society. They had made known their desire to the Council at an early day, and the Council, in accordance with its policy to render its decision, selected Boston pursuant to the desire of the resident members. The last convention of the city of Boston had been held in November, 1885, at which time the membership of the Society was 605, and there were 130 members in attendance.

In 1902 the membership had become 2,458, and the attendance of members, ladies, and guests exceeded 863, of which 375 were enrolled members.

Some pride was taken by the Boston membership in the fact that this enrollment was the largest in the history of the Society, and surpassed even the best record of attendance at the annual meetings in New York City.

The sessions for the reading of papers, and the headquarters for the transaction of convention business were in the rooms of the Department of Mechanical Engineering of the Massachusetts Institute of Technology, on the second floor of the building known as "Engineering B."

The drawing tables had been removed from one of the larger rooms, which served as an auditorium for the reading of papers, and special rooms were furnished also for the use of the visiting ladies and the Ladies' Committee of residents. The President of the Institute, and the Professor of Mechanical Engineering and his associates, left no effort unmade to make the meeting a success upon its administrative side. The members were accommodated in the Hotel Brunswick and in the other hotels in the neighborhood of Copley Square.

The opening session was held in Huntington Hall of the Rogers Building of the Institute, on Boylston Street at 9 P.M. May 27th.

President Henry Pritchett of the Massachusetts Institute of Technology was in the chair, and on the platform with him were the Past Presidents of the Society, the members of the Council, and Mr. George A. Kimball, President of the Boston Society of Civil Engineers.

Mr. Francis H. Boyer, Chairman of the Committee of Arrangements, welcomed the Society on behalf of his associates, and introduced the speakers.

It was a source of keen regret that the President of the Society, Mr. Edwin Reynolds of Milwaukee, was prevented by ill-health, and a combination of other circumstances, from being present at the meeting. His place at the opening session and at all the other meetings was taken by Vice-President James M. Dodge.

After the addresses the members adjourned to the library of the Rogers Building on the floor below, where a reception was held by Dr. Pritchett, Mr. Kimball, Mr. Boyer, Mr. Dodge, Mr. Church, and their ladies, after which a collation was served, and the meeting became a social reunion.

Second Session. Wednesday Morning, May 28th.

Vice-President Dodge called the second session to order for the transaction of business at ten o'clock in the meeting room of Engineering Building B of the Massachusetts Institute.

In calling the meeting to order the Chairman asked an expression of opinion from the members on the question whether the general desire was that the rules formulated some years ago, whereby a presentation by any one member of oral discussion on a paper should be limited to five minutes should be enforced, and stated that these rules had not been enforced in recent years because many participants in debate had seemed disinclined to abide by them. If the discussion had been elaborately prepared and reduced to writing, the limit would be ten minutes; but any member might give his time to another in a debate if in his opinion the interest and importance of the discussion should warrant this procedure.

On putting the question to the meeting, it was unanimously voted that the rules limiting the time of debate should be regarded. The Chairman said that he would have his watch before him and on the expiration of the time limit he would rap upon the table, and he trusted that no one would misunderstand or would be offended if no exception was made in his case.

The first order of business was the Report of Tellers, presenting the action of the membership upon the candidates seeking election in advance of the Boston meeting. Their report was as follows:

REPORT OF TELLERS.

The undersigned were appointed a committee of the Council to act as tellers, under Article 11 of the Rules, to scrutinize and count the ballots cast for and against the candidates proposed for membership, in their several grades, in the American Society of Mechanical Engineers and seeking election before the XLVth meeting, Boston, Mass., 1902.

They met upon the designated day in the office of the Society, and have proceeded to the discharge of their duties. They would certify for formal insertion in the records of the Society to the election of the following persons, whose names appear on the appended list, in their several grades.

There were 556 pink ballots cast, of which 8 were thrown out because of informalities. The tellers have considered as informal a ballot which was not endorsed.

C. W. Hunt,
D. S. Jacobus,
C. H. Corbett,
A. M. Waitt,
} *Tellers of Election.*

As Members.

Baker, William E.
Bannister, Jno. C.
Blood, Chas. W. H.
Blossom, Francis.
Brock, Walter Irving.
Bulkley, Joseph N.
Bunting, Douglas.
Caldwell, George B.
Chambers, Frank G.
Chase, Charles H.
Church, Wilmer.
Clegg, Robert I.
Collett, Samuel D.
Cook, J. F.
Davenport, R. W.
Davis, Francis H.
Dillon, Frederick N.
Dinkey, A. C.
Eynon, Thomas M.
Farrar, Charles O.
Furman, Franklin De R.
Green, Thomas W.
Gridley, George O.
Hildreth, W. A.
Hiller, N. H.
Hodgkinson, Francis.
Hosmer, Sidney.
Jenks, Richard P.
Kennedy, J. J.
Kirton, Walter.
Landon, A. Archer.
Lawrence, Schuyler.
Leeds, Pulaski.
Linch, Edward P.
Ludlow, Charles G.
Lyons, James W.
McFarland, A. R.
McIntosh, William.
MacCord, Charles W.
Moore, L. C.
Moultrop, I. E.
Orrok, George A.
Pinkerton, Andrew.
Porter, Arthur T.
Porter, H. Hobart, Jr.
Roche, John A.
Roe, Walter E.
Scott, Clarence N.
Sells, Osborn P.
Smith, Allen C.
Smith Augustus.
Threlfall, William V.
Tracy, Theron H.
Vaughan, Charles Alfred.
Whittemore, John R.
Whyte, Frederic M.
Whyte, John S.

Promotion to Full Membership.

Abell, H. C.
Baldwin, Abram T.
Barnes, S. G.
Boenig, Robt. W.
Bowman, Franklin M.
Burnham, Harry A.
Cowan, Freeman B.
Crosby, William W.
Eberhardt, Fred. L.
Mason, Daniel A.
Robinson, Edward.
Shepard, F. E.
Towne, Frederick T.
Worden, Euclid P.

A Associates.

Ackerman, William W.
Chase, F. A.
Fickes, Edwin Stanton.
Hanson, Walter S.
Hill, Walter L.
Hughes, Edward F.
Kaufman, Emanuel.
Krehbiel, Frederick A.
McClaughry, C. C.
Merrill, Frank A.
Pearson, Hiram.
Reeder, N. S.
Russell, William H.
Sharpe, Lucian D.
Sherman, Charles K.
Viall, William A.
Waite, Edward B.

Promotion to Associate Membership.

Griess, Justin, Jr.

As Juniors.

Austin, William Sumner.	Gump, Walter B.	Oliphant, J. Norris.
Baldwin, George M.	Hall, Rodney D.	Oliver, E. C.
Bradenbaugh, Frank E.	Hampson, C. M.	Parish, William F.
Braman, Samuel N.	Hardy, Carl E.	Potter, H. W.
Brown, Dickson Q.	Harris, Clifford R.	Price, Norman I.
Buffum, Frederick D.	Harwood, Charles F.	Reynolds, John P., Jr.
Case, Willard L.	Hayward, Elmer L.	Robinson, G. P.
Clark, Walter Lemuel.	Jett, Carter C.	Rooney, Philip P.
Collins, Fred.	Johnson, William M.	Schenck, Charles, Jr.
Day, Charles.	Kavanaugh, William H.	Slichter, Walter I.
Dodge, Kern.	Kutter, Herman L.	Stovel, Russell W.
DuBourg, Henry H.	Lewis, Arthur Schultz.	Streeter, Lafayette P.
Farmer, John T.	Libby, Malcolm M.	Terry, Charles D.
Faulks, James B., Jr.	McGowan, Francis X.	Thorp, Frederick P.
Forbes, H. C.	Mayer, L. G. C.	Whipple, Eugene B.
Garcelon, Charles A., Jr.	Metz, Walter R.	Zimmerman, W. H.
Goldie, Alexander R.		

This was the only formal business listed upon the docket, and at its close the Chairman announced that new business was in order.

The Secretary read an invitation from Prof. Edgar Marburg, Secretary of the American Section of the International Association for Testing Materials, inviting the members interested in these subjects to attend the Fifth Annual Meeting of that body at Atlantic City, June 12th, 13th, and 14th. No action was taken on this invitation beyond its public announcement.

The following resolution was then presented by Mr. F. J. Miller in the form of a notice to amend the Rules by bringing up this resolution as an amendment to be considered at the annual meeting in December. Mr. Miller's resolution was as follows:

Resolved, That these Rules may be amended by a letter-ballot, at any annual meeting by the assent of two-thirds of the members voting, provided that written notice of the proposed amendment shall have been given at the preceding regular meeting, and that a blank ballot, accompanied by the mover's reasons for the change, if he desires, and a comment on the same by the Council, if it so elects, shall have been mailed to each member entitled to vote, not later than the time of mailing the ballot for officers of the Society. The ballots shall be voted and the result canvassed in the manner prescribed in Articles 33 and 34. The tellers shall immediately certify the result to the annual meeting, when, if the certificate shows that two-thirds of the votes cast are in favor of the amendment, it shall immediately take effect. This resolution is not intended, however, to deprive members of their right to vote by proxy, if they so elect.

After reading the resolution Mr. Miller added in explanation his view that, while the amendment of which he gave notice would perhaps be of a temporary character, in view of a proposition which he understood was to come before the meeting for the appointment of a committee to give consideration to the general question of amending the Rules as a whole, yet if this could be accepted at this time, and could receive action at the next annual meeting, then the questions brought up by propositions to amend the Rules could be treated by the method outlined in the above resolution, and the Society would then have an opportunity to vote by the method which it provides upon the method of amendment, as well as upon the other questions which would be considered by the committee.

On request, the Secretary read the articles referring to the methods of amendment. In the discussion of the general question raised by Mr. Miller's resolution, Messrs. Jesse M. Smith, H. R. Towne, C. W. Baker, C. W. Nason, G. C. Henning, C. W. Hunt, and H. H. Suplee spoke as follows:

Mr. Jesse M. Smith.—It seems to me evident that no discussion of this question can be had at this time, as according to the rule we cannot act upon it until the annual meeting, and this is simply a notice of what will be presented at that time. I am heartily in favor of this resolution and hope it will pass, because it puts out of the way a great many vexatious questions which arose at the last annual meeting.

Mr. Henry R. Towne.—Mr. Chairman, I think it pertinent at this time to call the attention of the members to a fact which developed at our discussion at the meeting of last December, namely, that every member of the Society has a legal right to appoint a proxy to represent him at any business meeting of the Society. This fact has not been appreciated by the members, and the understanding has been, on the contrary, that the votes counted at a meeting could only be those of the members present at such meeting. The amendment which has just been introduced contemplates broadening the ballot on business questions by permitting letter-ballots to be cast by members unable to attend the meeting; but over and above any such rule is the legal right which each of us has to appoint a proxy to represent us at a business meeting, and there are reasons, Mr. Chairman, which it seems to me may, in many cases, make a proxy the better mode of representation. For example, if it were known in advance of this meeting

that a certain business question was to come up for action, each of us might have an opinion upon it, so far as the facts were before us, and be prepared to express our opinions by letter-ballot; but it is also possible that if we could be present personally at the meeting, and could hear the discussion of the subject, the further enlightenment we would get in this way might modify our view and cause us to vote differently; and therefore it is the better mode of representation, usually, for a person who is unable to attend a meeting, to appoint a proxy to represent him, if that proxy has his confidence and knows his general stand on the question at issue, and to give such proxy the right to modify his action in the light of the discussion that takes place at the meeting. I understand, Mr. Chairman, that this is simply a notice of an amendment which will be brought up for action at the annual meeting in December.

Mr. C. W. Baker.—The purpose of the amendment of which notice has just been given is to establish the letter-ballot in the Society in connection with amendments to the Rules. With that purpose I am heartily in sympathy, so much so that at the New York meeting last December I gave notice of an amendment designed to effect the same thing. That amendment was discussed by the members present at the New York meeting; some amendments were made in it and it was finally approved by a vote of the members present. Under those circumstances I do not see but what it will have to come up for action at the coming December meeting. I do not see that I would have any right to withdraw it, notwithstanding this second amendment which is now proposed has the same end in view.

Moreover, since that time I have conferred with one of our Past Presidents, Mr. C. W. Hunt, and at his suggestion I have added a clause requiring due notice to be given the Council of any proposed change in the Rules. I will read the amendment as it now stands.

Strike out Article 45. Substitute in its place the following:

"At any regular meeting of the Society any member may propose in writing an amendment to these Rules, a copy of such amendment having been filed with the Council at least ten days before the opening of said meeting. Such amendment shall be taken up by the Society at the following session of the same meeting and shall be subject to discussion and amendment and to final acceptance or rejection by a majority vote of the members present and voting. If it is finally accepted, it shall be submitted to a letter-ballot of the entire vot-

ing membership of the Society; such ballots to be sent out at the same time as the next succeeding ballot for the election of members. A majority of the ballots cast shall adopt or reject the amendment."

I do not know that it is necessary here to go into a discussion of the relative merits of the two amendments. One thing I wish to point out briefly: that my amendment does something which the other amendment does not—doubtless through oversight of the member who prepared it. The other amendment opens the door to subjecting the Society to the expense of sending out for letter-ballot any amendment proposed by any member. Under the form I propose, any such amendment must run the gauntlet of a regular meeting, where it can be discussed and amended, and it must have a vote of approval of that meeting before it can go out to letter-ballot.

A number of members have agreed with me that a majority vote would then be sufficient for its approval. We ought not to make it too difficult to amend the Rules. I therefore submit the above amendment for such action as the Society chooses to take at the next December meeting.

Mr. Nason.—Aside from other differences between the two amendments, one of them calls for a two-thirds vote to pass an amendment, the other for simply a majority. If the two amendments could be harmonized in form so that the difference between them would be on this one point it might be better.

The Chairman.—I think that suggestion is a very good one. I think possibly that can be arranged by the mover.

Mr. Gus. C. Henning.—I should like to call attention to the resolution on the subject offered by the Finance Committee which will cover the whole case. Taking into consideration Mr. Miller's and Mr. Baker's proposed amendments, and those which I offered at the last meeting, we have so many before us now that evidently our Rules are unsatisfactory to a great majority, and something ought to be done to get them into a shape which will be satisfactory to every one. If this committee be appointed and all of the various suggestions offered be assimilated and joined together, or the best of them be selected and then brought in one general report before the membership to be acted upon at the December meeting, we shall come to some conclusion as to what to do. We have found that all that is necessary now is for one member to offer an amendment under Rule 45, and that such amendment must then be published to the membership and taken up. That is

hardly sufficient. It seems that any amendment proposed should first be submitted to the Executive Committee or the Council to see whether it deserves being laid before the Society. Now, under the resolution submitted this difficulty will be avoided, and the Rules and Constitution may be arranged so that these many discussions and consequent changes will not arise, and I think, that we cannot take any action at this meeting upon any amendment offered, and must wait until December according to our Rules (which, of course, is a hardship to us). Under our present constitution we have no alternative but simply to wait and to see that our Council puts everything into the best possible shape to give us an intelligent statement of the present condition of our Rules, and of those amendments which they deem wise to have embodied in them.

The Chairman.—I think that matter will be brought up at this meeting.

Mr. Towne.—Mr. Chairman, in order to give effect to the suggestion of the Finance Committee to which Mr. Henning has just referred, and also to give effect to what I believe is the sentiment of the Council, I will offer this resolution:

Resolved, That the Chairman of this meeting appoint a nominating committee of three members here present which, before the close of this convention, shall report the names of three other members of the Society to constitute a Special Committee on Rules and Methods, which latter committee shall take under advisement the whole subject of the Rules, by-laws and business methods of the Society, including such changes or amendments as have been or may be proposed by members, and shall submit its conclusions and recommendations to the membership in a report which shall be delivered to the Secretary not later than October 15, 1902, and which the Secretary shall thereupon cause to be printed and distributed to the membership not less than two weeks in advance of the next annual meeting of the Society.

The resolution was seconded.

The Chairman.—Gentlemen, you have heard the resolution just made which has been duly seconded. If there are any remarks we are ready for them; if not, I will put the question.

Mr. C. W. Hunt.—Before the question is put I think the time specified is too short to accomplish the work. We are now approaching the hot season when many of the members will separate, and not return before the first of September. That will give the Committee only thirty days to revise the Rules, and consider the various suggestions which come in. It is possible when that Committee is appointed they may wish to send a circular to the whole

membership, asking for suggestions, amendments, or alterations, or any notes which may be of interest to the Committee. That in itself would take some time. It would also take time to digest the replies, and I think an amendment of the Rules which is to stand for many years ought to take more time, or that the resolution should be changed so that if necessary they could make a report of progress at the next meeting.

The Chairman.—I would ask Mr. Towne whether the report mentioned in his resolution has to be made by a certain date, or if the words "if possible" could be inserted?

Mr. Towne.—The resolution as it reads is that the Committee shall submit its conclusions and recommendations in a report which shall be delivered not later than October 15th.

Mr. Chairman, I agree with Mr. Hunt; the time is somewhat short; but on the other hand I believe that it would be possible for the Committee to have some report at the meetingin December which the membership can discuss, and which will lead perhaps to still further improvement in the proposed changes. Whether so or not, under our present Rules, I think I am right that no final action can be taken for a year from next December, because Rule 45 states that notice of a proposed change must be given at a previous meeting, and action taken at the next annual meeting. Now, we are not ready to give notice of these changes at this meeting; therefore, we shall not be competent to act upon them at the next annual meeting, and as they must be acted upon at an annual meeting, that holds them over until the annual meeting in the fall of 1903, so I think we are going to have ample time anyhow, and that our Committee ought to try to do something which would bring the matter before the membership at the meeting in December.

Mr. C. W. Hunt.—The wording of the resolution is mandatory. If the resolution offered by Mr. Miller is passed it will dispose of the method of changing our by-laws in an easy and satisfactory manner. Then there is no necessity for great haste that I can see in amending our Rules. I think the Committee should have more time for their work. Mr. Henning has offered a series of amendments of great volume and importance proposing to follow in our Society the work of the German Engineering Societies of a kindred nature. This should be carefully examined by the Committee, which would take more time than is allowed by the resolution.

Mr. Jesse M. Smith.—It would seem to me unfortunate if Mr. Miller's resolution should be confounded with that which Mr. Towne has just offered. It seems to me that they are entirely different.

The Chairman.—Mr. Hunt understands that.

Mr. Smith.—I was speaking more to Mr. Towne's resolution. As I understand Mr. Towne's resolution, it is to the effect that these two resolutions which were offered before his should be referred to a committee. I may have misunderstood it; but it seems to me that the resolution offered by Mr. Miller is simply for the purpose of expediting and simplifying the mode of procedure. If that resolution is passed at the next annual meeting, and I hope it may be, it will simplify the problems to be decided later on, in regard to proposed amendments, and will enable every member to vote by letter. It is merely for the purpose of simplification of the machinery of the Society.

Mr. H. H. Suplee.—I think it is clear from the Rules that Mr. Miller's resolution can only be acted on by the Society at an annual meeting, and is not referable to a committee. Both Mr. Miller's and Mr. Baker's resolutions are simply notices, and must be laid over until the fall meeting. In regard to Mr. Towne's resolution it really has a year for consideration, because the committee's report could not be acted on until a year from next fall. Hence the resolution provides for as prompt action as possible.

At the conclusion of the discussion on this resolution it was passed. Mr. F. J. Miller then read the following communication in comment upon a report which the Council had prepared, and had ordered to be distributed to the membership covering the questions of administration, accounting, and methods which had been pursued in the conduct of the Society's affairs.

Mr. F. J. Miller.—I think it will be agreed that this report, in which the Council (I am tempted to say for the first time) takes the members of this Society into its confidence and places before them a complete statement of the Society's affairs, forms an excellent basis for intelligent action by the membership; and this confidence, I am persuaded, is not misplaced. This Society is composed of grown men, most of whom are more or less trained men of affairs, and those qualifications which entitle them to membership entitle them to know, to discuss, and finally to decide upon matters of business connected with the Society. Indeed, I could wish that the report might have gone further and still more

into detail, and that we might have been informed, for instance, not only what the ratio is between our expenditure for the Secretary's office and that of other societies, but also just what amount we do spend. I think there should be no secrecy whatever about that, but that every member should be considered as entitled to know all about it.

There are a few points in this report to which I desire to call attention, and concerning which it seems proper to ask a few questions: At page 3, under the heading B and Paragraph No. 2, the statement is made that during the twenty-two years of the Society's existence it has accumulated a surplus of over $73,863. It is evident from this that the average receipts of the Society have exceeded its average expenditures (by about $3,350 per annum). If, during the past few years this annual surplus has been turned into a deficit, then it is the part of wisdom to carefully consider the reasons therefor, and then to consider whether the increased expenditure per member is wise or necessary, and I have no doubt that a majority of the members would favor such increase of dues as had been shown to be clearly necessary after proof that the Society's affairs have been for a time well managed —managed in a business-like manner; but not otherwise.

As regards that part of the report which refers to the Society's former and newly adopted method of bookkeeping, under heading C at page 4, it may be observed that, while the present method is adopted to give the officers and members a much better and clearer idea of our pecuniary affairs than was readily obtainable previously, yet the fact is, as one member expressed it, that "a balance sheet is not a new or modern invention;" on the contrary, it is an old and familiar thing, the very great usefulness of which has been amply demonstrated through many years of business experience. In this connection it may be remarked that in the latter part of the last paragraph on page 4, there appears what is perhaps an unfortunate expression; the last sentence reading, "The Society *appears* to have been able in one year to make a substantial reduction of its debt, etc." Now the word "appear," it seems to me, ought not to have entered into the report. It deals with a matter of bookkeeping, and the statement should indicate precisely, and certainly, to a cent, just what the Society has been able to do, and there ought not to be, and I believe as a matter of fact there are no "appearances" about it. It is, or at least ought to be, a definite, exact and complete statement.

Under heading D at page 5, the character of the published volumes and the quality of the papers printed by the Society are referred to, and it is stated that, " so far from curtailing these, the Society should expand in the direction of more papers of wider interest, of superior quality and usefulness, even if it must expend something more to attain these results." I think every member will agree that an improvement in the practical usefulness of the papers presented before this Society is desirable; but can such improvement in the papers be secured by the mere expenditure of money? It seems to me doubtful, but possibly different, though not necesarily more expensive methods might readily bring about such an improvement.

In the last paragraph at page 5, the staff employed in the office is referred to and in that there are two classes, that is, the officers and the staff. I think the general impression among the members has been different from that which is stated in this paragraph. For one thing, the newly-appointed assistant to the Secretary is not classified, I believe, in this paragraph either as an officer or as a member of the staff. It would be a little more satisfactory to the members at large perhaps if there were some indication of the extent to which Mr. Hoadley's time is devoted to the work of the Treasurer and to that of the Secretary, respectively.

Though the conclusion of the Council as expressed toward the latter end of this paragraph will probably be accepted by many, I think there are many other members who will not be disposed to accept it as the final conclusion. There is a quite prevalent and perhaps growing conviction that this Society will never be able to do all that it should do; nor to develop the degree of usefulness it should develop, or might develop, until it has a Secretary who is not only efficient and business-like, but who can devote his entire time to the affairs of the Society; and will have no other interests which he may consider paramount. I do not pretend to say whether this view is correct or not—and indeed I am not yet satisfied in my own mind regarding it—but this much I feel sure of; *i.e.*, that the question should receive careful attention and the views of the members should be obtained and considered in relation to it. I think it will be found that, generally, they will be less interested in knowing whether or not we pay more or less than another Society, than in knowing whether or not we are doing the best that we can do.

At the beginning of paragraph No. 3 on page 6, the cost of

operating the Society's house is given as $3,783 per annum, and figures are given to show that the minimum space that would be required in which to do the business of the Society would cost nearly as much if rented, and perhaps more. I doubt if there is as much profit in the mere renting of property in New York City as these figures indirectly show. Without going into figures at all it seems on the face of it that the maintenance of this house is an expensive luxury, and the figures given are not I think sufficient to dispel this impression. I believe the amount stated as the net cost of operating does not include interest. Certainly the interest actually paid out on the mortgage indebtedness should be included, and in fact interest at say 4 per cent. on the entire valuation of the property should be included, and 4 per cent. of $85,000—$3,400 should be added, making the total net cost nearly double the amount given. Admitting the force of what is said about the advantages of the Society owning its own house, the question is still open as to whether we are not paying rather dearly for these advantages—especially when it is considered that the house has become totally inadequate for its chief purpose.

Near the top of page 7 it is explained why the cost of operating the Society per member does not fall so rapidly as it would, or might, under other circumstances. Of course we all understand that where fixed charges enter into an expense account, expense per capita cannot be reduced in proportion to increase of membership; but as a matter of fact the report indicates that the expense per member has not fallen at all within the past few years, but has increased, and the members of the Society will, I believe, generally not be entirely satisfied until that increase is satisfactorily accounted for, and probably not until the increase is arrested.

Referring to the second paragraph under heading E, which are recommendations for the future, I believe that no member of the Society believes that it should, in language of the report, hold its breath and mark time and fail to progress. It is simply a question of how we should progress, or in what way we should progress. Rightly or wrongly very many members now believe that we were, last fall, in danger of attempting to progress along a path in which no real or satisfactory progress would have been possible. They believe that the Council was led to inadvertently approve measures which not a single member of that Council would have considered for one moment in connection with his own

business, where he alone would have been responsible for the results. It does not follow that these members—sincere well-wishers of the Society I am sure—are in favor of the Society's holding its breath and marking time simply because they do not think it is wise to follow a certain specified course. My belief is that the quality of the *Transactions* can be improved without materially increasing the cost of them, and it is open to debate, doubtless, as to whether we do not publish a good deal of matter that is of little value. Those who are at all acquainted with the printing business know that tables in printed matter are an expensive luxury, and it is doubtful if any large proportion of the members of this Society derive much benefit from many of the expensive tables giving long detailed accounts of tests of engines and boilers which so abound in our *Transactions.* Perhaps the gist of these things might in many cases be given without publishing page after page of long tables which are of doubtful value. And much the same may be said of fully worked out mathematical demonstrations.

The best and perhaps the most hopeful feature of this report is to be found in paragraph numbered 7 at page 16, where the Finance Committee recommends that a committee be appointed to make a general revision of the Rules of the Society, etc. In favoring such a resolution, I do so because it will enable any member who desires to present to this Committee, either in person or by mail, such changes or ideas as may seem to him calculated to increase the Society's usefulness or improve its standing. This Committee, then, may take all such ideas under consideration and may formulate proper Constitution, By-Laws and Rules to be submitted to the members for their approval, amendment, or rejection. The right of voting by proxy having been established, every member of the Society may feel sure that the wishes of the majority of the members can be carried out. This, it seems to me, is not the time to attempt a general discussion of the things which the Society should do or should not do; such discussion should be carried on later, either at the fall meeting in New York or elsewhere, in connection with the consideration of the work of the Committee which this resolution provides for the appointment of. It seems to me that this is a good opportunity to set in motion the machinery or forces which may eventually lead to a betterment of the general condition of the Society, whose best interest I feel sure we all have at heart.

This report was before the meeting by virtue of having been sent to every member in advance of the meeting, and is issued as an Appendix to the current volume of *Transactions*. The discussion on the general questions raised by that was as follows:

Mr. Harrington Emerson.—There are quite a number of points to which I would like to call the attention of the Society and of the Council, but I will limit myself at the present time to a single one. In this report it is stated that the Society has accumulated a surplus of $74,000 during its existence. In looking over this report it seems to me that probably $25,000 of the surplus is due to the increase in the value of the building alone, and I also find that $13,000 of that is due to the arbitrary increase in the value of the *Transactions* of the Society over the value put upon them by the committee that was appointed to appraise their value, making those two items alone $38,000—fully half the amount of the so-called surplus; and it is not stated anywhere in this report to what extent the life dues or the bequests that the Society has received have gone in there and been counted as part of the surplus, and it rather seems to me, from looking at this report as if from the very beginning, the Society had practically been running behind. But the thing that I would particularly like an explanation of is, why the Council or the Joint Committee felt authorized arbitrarily and without any explanation whatever to increase the appraised value of the *Transactions* of the Society.

Mr. Towne.—Mr. Chairman, the first point taken by the gentleman who has just spoken is entirely correct, and I was on the point of rising to correct the misapprehension which Mr. Miller had as to the exact facts concerning the present surplus. Mr. Emerson is right, that $25,000 of it is the "unearned increment," as Henry George calls it, arising from the increased value of our real estate in New York. Another $10,000, or probably $12,000, is due to what Mr. Emerson correctly refers to as the increase of the appraised value of our *Transactions*. There is another additional amount, which we are not able to ascertain definitely, but which the Secretary tells me may conservatively be placed at about $18,000, representing gifts to the Society, chiefly of our second mortgage bonds which were issued at the time we bought the house in Thirty-first Street, and all of which are now retired. So that, subtracting all of those from the surplus stated in the report, leaves approximately $20,000 of remaining surplus which

there is good reason to believe is accumulated surplus income—income in excess of current expenses. And, therefore, I think the statement is justified in Mr. Miller's comments that, taking the history of the Society as a whole, our total income has somewhat exceeded our total outgo. That is not true the past year or two, although we believe that the economies which have been put into effect recently are probably going to produce a balance, this year, on the right side; this depending, however, upon the decision that shall finally prevail concerning the disposition of receipts from life memberships and from initiation fees. Including those in our current receipts, the income of this year will unquestionably suffice to meet the expenses of this year.

The other point which Mr. Emerson refers to is the valuation of the books. I think I am correct in my recollection that the figure finally adopted is a mean between two extremes, the one extreme being the cost of production, and the other extreme being the value of the *Transactions* if sold at the price at which we are selling them and have sold a great many.

The one extreme is the mere cost of printing, and the other was the price for which we are actually selling the *Transactions.* We have sold in the past a large number of *Transactions* at that price. There is every reason to believe that in the course of time all of them, or the greater part of them, will be disposed of at that price. The figure adopted is the mean between these two extremes, and we think is a conservative one. It does not enter directly, however, into any question relating to the current expenses of the Society. I think there is one other item of interest that the members might like to know of, namely, that, at the time the accounts were made up as of September 30, 1901, the total indebtedness of the Society, outside of the mortgage debt, was $15,169. The corresponding indebtedness on the 15th day of May is $12,034.46. In other words, there has been a reduction of about $3,000 in the indebtedness during the past six and a half months.

The Chairman.—I might say that if any of the members have any points in regard to this matter, if they would reduce them to writing and send them to the Secretary it would be a great help to the committee and to the Council and to us all. We are all interested in this problem.

Mr. Jesse M. Smith.—There is another matter of new business that I would like to bring before the Society. We have heard a

good deal of the financial side of the Society's proceedings. Now, there is another side of it which is of vastly more importance, and that is the engineering side. This is an engineering society; not a financial institution. The only reason for its existence is because it furthers engineering projects, engineering questions of all kinds. Now, it seems to me that in these questions of economy, which are arising and which the Finance Committee and Executive Committee and the Council are doing their utmost to meet, we should not go to the extent of damaging the proceedings of the Society by curtailing to too great an extent. It seems to me that the proceedings of this Society are of vastly more importance than the saving of a thousand dollars a year or two thousand dollars a year. If we do not keep up the standard of the Society from the engineering standpoint, we can expect a greater deficit than we have yet had. Now, I offer the following resolution. That for the next annual meeting all the professional papers to be read at the meeting be printed and sent free charge to each member of the Society, sufficiently in advance of the meeting to permit discussions to be sent in by members who cannot attend the meeting. Sending out the papers in advance to every member of the Society has been the rule for the past four or five years. It is now proposed to curtail it and to send those papers only to such members as ask for them through a postal card, which is sent out by the Secretary. Now, it seems to me that it is of the greatest importance, particularly to those members who are not fortunate enough to be able to attend these meetings—and the percentage who attend is very small, three or four hundred out of a total membership of over two thousand—that something is due those members of the Society who cannot be present at the meetings. They are entitled to know what is going on. They are entitled to know the papers that are to be read, and they are entitled to know in time, in advance of the meeting, so that their discussions can be sent in to be read and become a part of the Proceedings. It is the Proceedings of this Society which make the Society valuable, and for at least three-fourths of the members that is the chief recompense which they have for the payment of their dues. Now, it seems to me that the members, particularly those who live at a distance from the place of meeting, are entitled to know what is going in in the Society before discussion of the questions have closed. Now they can only know of them in the published volume, which appears from a year to a year and a half

after the act. On this point of distributing the papers free in advance of the meetings among the members, I want to give some statistics which are the result of the work of the American Society of Civil Engineers. In their early history they did not publish the papers in advance of the meetings at all. Then they published a few, which were sent to members who they thought would be interested. Then they proceeded a step further and published them quite freely. During the past six years, as I understand from the proceedings of the Society of Civil Engineers, they have sent out those papers far enough in advance so that every member would have an opportunity of sending a written discussion. I read from page eleven of the Annual Report: "During the last six years all papers have been published in Proceedings in advance of the date set for their presentation, and nearly always sufficiently in advance of that date to enable distant members to be represented at the meetings by discussion in writing, if they so desired."

What is the result of that liberal policy on the part of the Civil Engineers? It is stated here: "Figures showing the average length of papers and discussions and the number of discussions per paper are perhaps the most significant and interesting, as they indicate during this last period a much wider and more carefully prepared discussion than obtained under the old system, and the increase, under these headings, over the previous average, is in length of papers an increase of 55.2 per cent.; in length of the discussions 52.4 per cent.; in number of discussions per paper 141.2 per cent." If the Proceedings of the Society represent the valuable part of the Society's work, it seems to me that this liberal policy on the part of the Civil Engineers is well warranted, although it costs more money, and that is the policy which has been pursued by this Society up to within the past year, and it seems to be highly desirable that this policy should be pursued even if it does cost the difference between printing two thousand papers for distribution at this meeting and the printing of two thousand more, while the type is all set up, for distribution to the membership at large. The difference in cost is the cost practically of the postage for sending out these papers to members. If we send out a postal card, it costs a cent and a half per member, but it only gives him a chance to see whether he wants the papers or not. In other words, it seems to me that the additional cost of sending every paper to every member of the Society is insignificant compared with the benefit which will accrue.

Mr. H. H. Suplee.—In seconding Mr. Smith's motion I would like to speak of the way in which the Society of Civil Engineers publishes its papers. When they first come out they are, as Mr. Smith has indicated, called Proceedings—they are in process of evolution.

They are sent out in periodical form at, I believe, pound rate postage. The discussions keep coming in through the year, and are published in the Proceedings as they are received. At the end of the year each paper is assembled with discussion on it, and the whole is published as *Transactions*—they have been completed. In that way they get the subject discussed very fully, and I think are repaid for the cost.

I should like also to call attention to Article 42 of our present Rules, which states:

> "The policy of the Society in this matter shall be to give papers read before it the widest circulation possible, with the view of making the work of the Society known, encouraging mechanical progress, and extending the professional reputation of its members."

I agree with Mr. Smith that anything which will curtail those fundamental purposes should be discouraged.

Mr. Emerson.—I would like to say just one word more bearing on what Mr. Smith has suggested. This, as Mr. Smith has said, is an engineering society, and it is a matter of some amusement to me that a society that has in it, or claims to have in it, and I believe possesses in it the best organizing talent in the world, should, in its own private affairs, be one of the most inadequately managed societies that it was ever my pleasure to be connected with. And one of the very first things to do before we get down to such details as sending out our *Transactions* and securing discussions, is to put our house in order, so that we will not run the risk of bringing discredit upon the whole mechanical engineering profession in the United States. Now, I believe, in looking over the system that has been here presented, that it would be perfectly possible to curtail the expense of this Society $10,000 a year, without interferring to the very slightest degree with its efficiency and with the publication of its *Transactions*, and so forth, and I would like to ask, if I believe this—having lived for three months, three or four months last—in the rooms of the Society and watched its daily operations there as a member, and besides having been connected with it—if I believe this, I would

like to ask the Vice-President to whom am I to present the facts on which I base that belief.

The Chairman.—In writing?

Mr. Emerson.—In writing or any way.

Mr. Towne.—By all means to the Society.

The Chairman.—The Society, I should say.

Mr. Towne.—It belongs to the Society, not to the Council. The Council has no secrets.

Mr. Emerson.—We are trying to do three different things in the Society; first, we are trying to run a gentleman's club, and as a gentleman's club the Society is a failure. It is not run the way a gentleman would like his club to be run, and we find the evidence of that right in this report. It costs $5,672 to run the house, and they only get $1,338 of income from it—from the rooms—as a gentleman's club. Taking the price charged for the rooms, the Society shows an efficiency of 28 per cent. That might do very well for the Diesel motor, but I do not believe it is very high efficiency for a gentleman's club. Either the price of the rooms should be reduced to the members, provided they were occupied to a large extent, or you could increase your income: you could do both things; you could decrease the price of the rooms and thereby afford more accommodation to the members, and you could increase your revenue.

Secondly, I think that the expenses of $5,672 could be curtailed. I have seen a great many evidences of waste in the management of the Society. Now, if we could cut down those as far as $2,000 a year, which I believe could be done, and we could increase our revenue from the price of rooms $1,000, there would make a difference right off of $3,000, and the house itself would be almost self-supporting, and there would not be any question of giving up our headquarters, because it costs us so much to run the house.

The second great division is printing. That takes up 47 per cent. of all our expenses. Now, I do not believe that the management of the Society has gone to different printers in New York and found out what their printing could be done for at the very lowest figure. I believe that Mr. Kent, in the publication of his "Pocket Book," secures very much better figures for setting up the type and printing, than this Society does, and in reading over this report I find when we want to borrow money we borrow it from our printer, and that we are absolutely in his hands, and we do not dare say anything to him, except to pay such bills as he

puts in; and I believe the same thing is true of the binding of the books of the Society, that the binding could be done for very much less as well as the printing, and that in those items also probably we could cut down our expenses with the proper kind of management—the kind of management that Mr. Kent uses in his business—fully $5,000 a year.

The third item is that of salaries, which takes up 25 per cent. of the income of the Society. That seems to be a very large item—25 per cent. for salaries. Now, I think very possibly we could secure just as good services as we now have, just as great ability, for possibly some saving—not as much as in the other directions, but I do not believe that over 15 per cent. of our income should be devoted to salaries. It would be much better to take a fixed figure, a certain proportion of all the dues, for salaries, and expand as we go along, rather than use up 25 per cent. and get into trouble. Those are the three divisions, the management of the house, the printing, particularly, and the salaries, on which I think we could make a saving of at least $10,000. Now, this report here is right straight through an apology. There is no aggressiveness about it. The Joint Committee have seemed to feel very timid, and I do not wonder that they felt timid; they ought to have felt timid with the kind of report that they bring to us here. We are told that the expenses of the Society increase, except in the matter of house, in proportion to the numbers, and one of the items in which it is mentioned that the expenses are going to increase in proportion to the numbers in printing. Now, if there is anything in the world in which expenses go down as numbers increase, it is printing. We print, perhaps, three thousand copies of our papers. What proportion does the setting up in type of those papers bear to the actual printing? Why, if we wanted to go in and get another thousand copies or two thousand copies, it would not cost us 25 per cent., not much more than 10 per cent. of what the setting up would cost, and yet we are told that as the Society increases, its expenses for printing are going to increase in proportion. Now, that is not true, and moreover in sending out the *Transactions*, it would be perfectly possible to print those that are going to be distributed on thin paper, so that we could send out, in accordance with the suggestion of Mr. Smith, all the *Transactions* or all the discussions of the papers that are going to come up on thin paper, so that for a cent, or for two cents at the outside, every member would receive them.

Mr. William Kent.—Mr. President, there is one point that has not been brought up in this discussion. It is the character of our *Transactions*. I have had occasion several times in the last twenty years to protest against the publication of some of the papers as unfit to print in the *Transactions* of our Society, but in every case the Publication Committee has printed those papers not only at great expense to the finances of the Society, but also at the expense of the reputation of the Society. I think we ought to have a larger Publication Committee, and that Committee should be divided into sub-committees of experts on certain branches, so that a paper on steam engines, for instance, should not be printed without the consent of the two members of the Committee who are experts on that subject, and so with papers on other subjects. In the past we have had a great number of papers that should not appear in the *Transactions* at all. They are no credit to us.

Mr. Nason.—Mr. Kent as ex-member of the Publication Committee must be fully aware of the very great difficulty of getting papers of the character desired for the *Transactions*. Various expedients have been tried and suggestions made; you are all familiar with the postal cards and other methods which have been adopted to induce members to give us what we want, but with only moderate success.

Col. E. D. Meier.—I heartily agree with the mover of the resolution, that it is a very good thing to have all the papers before every one of the members—however, with this previse, that the member that gets them wants to read his papers. I object to having them printed and sent out at a considerable expense for postage, simply to go into the waste-paper basket.

Now, there was a very excellent method adopted by the Secretary about a year ago, and that was to send out a synopsis of the paper, and that can be sent out, I think, for a cent—sent to every member, and then let every member choose which papers they want to read after seeing that synopsis; and they will send for those they want to discuss, and the others need not be printed, except in just sufficient number for the meeting itself. There is another point that was brought up by my friend Mr. Kent—that that would give a very good guide to the Secretary, as well as to the Publication Committee, in regard to the desirability of publishing certain of the papers at all. Now, I remember, in one of our late meetings there was a paper which was simply an advertise-

ment of a tolerably worthless device, and it could not have got into any trade paper, without being paid for at so much a line.

Mr. Gus. C. Henning.—I was a member of the Publication Committee and I had cause to speak in refusal of certain papers. At the same time some papers were offered at meetings which were not submitted to the Publication Committee. One of the papers to which I refer was a general description of the South Boston Terminal Station, another was the memoir of Sir Henry Bessemer. The first paper forms a large proportion of the *Transactions* of that year. The second caused some very hard feeling. How they got in I don't know.

In regard to the present method of distributing the papers in advance, I should say that this year's procedure is entirely satisfactory. Perhaps the summaries were not exactly what they might have been; but those who wished to discuss these papers certainly received them in ample time before the meeting. I do not think it is necessary to distribute papers gratuitously to the whole Society and then simply have them thrown into the waste basket. Those who wish to discuss the papers will get them by the method which is now in vogue in ample time before the meeting. If the papers are not presented, so that they can be prepared in ample time, they should be laid over and held for the next meeting. If we have three good papers at a meeting, with ample discussion, it would be better than twenty which would lead to little discussion and add no credit to the Society in its *Transactions.*

Mr. George Dinkel.—I think the point that Mr. Kent makes is the best thing that could ever be brought about. The very paper which is mentioned here as being an advertising scheme was distributed—I myself received three copies—as being read before the Society. Such a paper should never be admitted. I do not see why this Society should be used as an advertisement. It is not alone used as an advertisement for the papers, but it is used as an advertisement by members, for certain manufacturing concerns; and I think a good many of the members will agree with me, that when certain persons come into their office to show the devices which they have to sell, you will find there coats thrown open and the Society pin exposed or shown, with the object that by thus telling of their membership to the Society, it will help sell, or advocate whatever they are selling. I believe that we cannot any too soon raise our dues and requirements of this Society and keep it on an elevation, or standard, worthy of the name of the

American Society of Mechanical Engineers. I do not think we can put it on any too high a scale or standard.

Mr. Emerson.—Do you mean as to dues?

Mr. Dinkel.—I have no objection to having the dues raised. I think the dues should be raised. I think we need it. I think that all the papers should be sent out to each and every one. I do not want a postal card sent to my office asking if I want any of the papers as given on the postal card. I probably may be away at the time and will have to send another postal card stating that I do want such and such a paper. Further, to do this a man will at all times have to have the postal list to know what papers are to be read. All papers to be read should be sent in due time; then if a man is a member of this Society and does not think enough of the Society to look over these papers, rather than throw them in the waste-basket I think he ought to give up being a member of the Society.

Mr. T. R. Almond.—I believe that I am speaking to the motion when I raise the point, after listening to the discussion, that we are coming to the question at issue. The issue to my mind is, whether this Society shall continue. If we gradually get into debt we cannot continue to exist. Therefore, one of the first things to consider is how to economize, so that we may have a continued existence. Now, while I quite agree with Mr. Smith's motion that the papers should be broadly sent, just as charity should be given—I would be willing to lose ninety per cent. given for charitable purposes if ten per cent. should reach its destination and do the good that is intended, . . . we would be economizing this year if we act as I believe the Council have suggested, viz.: curtail the number of papers to be sent. My experience is, that there is not one paper in twenty which I want to see, and I believe that to be the experience of a large proportion of the gentlemen present.

Mr. Daniel Ashworth.—I have listened with a great deal of interest to the discussions upon these propositions, and I wish to say at the outset, that I am heartily in favor of sending these papers out as they have been sent heretofore. It has been truly said that there are many who cannot attend these meetings, and each paper should be put into the hands of every member of this Society, and not in any cheeseparing way on thin paper, or anything of that kind, but in a first-class condition on first-class material. The objection to papers that bear upon their face an adver-

tising idea is wide-spread through the membership; but if I understand our system, we have a committee who are supposed to exercise their judgment in regard to the merit of papers, whether they are fit to be presented before this body. It is within their purview, I believe, to decide whether a paper is or has the color of an advertising medium; if so, they should rule it out; if not, it should go out before the membership. Unfortunately, there have been papers read and presented before this body, which should not have been presented; but let this committee exercise that judgment within their power upon such a feature as that and let our papers be legitimate and thorough; then such papers should be sent to every member of the Society and on first-class material. We cannot swing this pendulum to the other extreme and get down to this matter of small business and throttle the enterprise of an institution like this Mechanical Engineers Society, a Society which stands without peer in our country and challenges admiration abroad.

If I were to be asked what were the most valuable books in my technical library I would point with pride to the *Transactions* of the American Society of Mechanical Engineers, and I would further say, that if I go into an office, into an engineer's office, and see upon his desk a set of papers from this Society in advance, I would have a spark of pride to say that that was a Society which had the power and had the right and had the manhood and the sterling quality to keep pace with other societies throughout the world in having sent forth its papers so that every member, no matter how humble he may be and how limited in his circumstances or how his business is situated, can have them before him and send his discussion in writing and be fully prepared to enter upon it. Why, gentlemen, it is time that we were shutting down upon this idea of parsimony. Let us all say that we will take measures to so shape ourselves that we will do everything right, everything first-class; then we will say to the world that "No pent up Utica contracts our powers."

Mr. Towne.—Mr. Chairman, I think this is the most profitable meeting I have attended for a long time. It is just the kind of talk, Mr. Chairman, that we want to hear from the members. The Society needs, I won't say reorganization or reconstruction, but *reawakening*, and this must come from the members, not from the Council or from the officers of the Society. The work of a body of this kind originates from the members. They have got to

do the work and put the life into it. The members have been leaning too heavily on the Council, the Council has been leaning too heavily on the Secretary; too much has been left to committees without seeing that those committees were doing their work. There has not been the right spirit in the Society. We want to get back again to the spirit we had in earlier years. We are going to get there, and with that spirit reawakened you will find that most, if not all, of these difficulties will disappear. In justification of what I have just said is the fact which has just been mentioned here, of papers passing into the *Transactions* without knowledge on the part of the Editing Committee. I know from personal experience that this has been the case. I know that the Committee has had to pass papers at times without the opportunity to read those papers—some papers that have passed in that way ought not to have gone into the *Transactions*. That was bad work on the part of the Committee. It was bad work that the papers were not put before the Committee earlier. The present report, which is in your hands and which has given rise to this debate, is another illustration. That report was not read by some members of the Council before it had to be issued. It should have been in the hands of all members of Council in time to consider it carefully before it was adopted. Personally, I think there are some mistakes of fact and of opinion in that report; but all of these questions come within the scope of the Committee which has been proposed, and the suggestions which are being made here will help that Committee in its work. Members should be encouraged, throughout the Society, to send in suggestions of this kind, and if the Committee does its work as well as I hope and believe that it will, I think we will soon see all of these difficulties put behind us, a new atmosphere created, and the Society started again on a higher career of usefulness.

But, Mr. Chairman, don't let us make the mistake of measuring that usefulness by the size of our dues. It is not the amount of money we pay in that determines the importance, character, and standing of an organization like this. It is the question of what we do with the money; or, still better, what we get that cannot be bought for any amount of money. Our *Transactions* have not deteriorated because of lack of money. Money will not buy what we want to see in those *Transactions*. It is interest, interest in the Society and its work, that has got to be brought out and which can be brought out, in ways which we

have discussed at various times, which alone can be relied upon to raise and increase the value of our *Transactions*. Certainly, Mr. Chairman, one of the first duties of a good engineer is to administer his work, whatever it may be, efficiently, and in that sense it becomes the management of this Society to establish economical and efficient methods of conducting its affairs and disbursing its funds before we ask the membership to pay in more money.

The proposition of the motion is now a mandatory one, an order to increase the expenses. On the other hand the Society is calling on the Council to make both ends meet. We are trying to do it; we are going to do it. I think it is possible that the proposed expense can be incurred this year. But I hope sincerely that the meeting will refer this question to the Council with discretion, leaving it to the judgment of the Council as to whether or not the extra work shall be done at this time—not deciding on our future policy, but simply as to what shall be done the present year—and I hope Mr. Smith will be willing to accept this amendment, thus leaving the question discretionary with the Council.

Mr. Jesse Smith.—This resolution which I offered applies only to the next annual meeting. For the meeting after that the whole question will have been sifted out by the Council, and their recommendation will probably be acceptable to the Society. I think it is a bad policy to retrogade. We have been sending out these papers to every member of the Society. It seems to me a bad time to go backwards, even if it does cost something to keep on; but what does it cost? What is the difference between doing as we have been doing and doing what is proposed to be done? The Secretary sends out a postal card. That costs money. He sends out a synopsis of the papers. That costs money to print and to send out. Now the question is, whether it would not cost less to print the papers and send them to every member of the Society, than to do this preliminary work of sending out postal card and then a synopsis of the paper and then putting the burden on the members of sending a reply postal card, and then having to send a considerable number of the papers after all. Why not be a little more liberal and send them to every member of the Society? The difference in the cost will be, it seems to me, insignificant compared with benefit.

Mr. Henning.—In view of the fact that all these matters are now before the Council, and that the Council has been doing the

best it can to make both ends meet, I move you, sir, to lay this matter on the table.

Carried.

Mr. Kent at the close of this discussion presented the following notice of an amendment to the By-Laws in relation to the duties of the Publication Committee.

Mr. Kent asked that the substance of this proposition might be referred to the Committee provided in the resolution offered by Mr. Towne, but that the present form of it might be considered as a notice under the present methods for the amendment of the Rules, so that if favorably reported on it might come up for consideration and action at the annual meeting. The proposed amendment is as follows:

"The Publication Committee shall consist of the Secretary of the Society and eight members, who shall be chosen by the Council at the beginning of each Society year. The Publication Committee on its organization shall appoint from its members special committees of two members each upon the different special branches of the general subjects of Mechanical Engineering which are treated in the papers submitted to the Society. Every paper available for presentation and publication shall be examined by the proper sub-committee and must be approved in writing by both members of such sub-committee before favorable action on its acceptance is taken by the Committee as a whole."

The resolution giving notice of a purpose to amend was seconded.

Mr. Henning then called attention to the operation of some of the Society's committees in the following communication, which he read.

Mr. Gus. C. Henning.—On May 22, 1896, a subject was brought before the Council, which has been allowed to slumber until quite recently. On page 223 of the manuscript minutes of the Council, occurs the following entry:

"The matter was presented of the desirability of taking steps to have the objections presented which engineers and manufacturers would feel to legislation making the introduction of the Metric System compulsory in America and that while it was for the interest of certain elements to secure the passage of such bills as the Stone Bill of 1896, there should be prepared and ready a statement of the objections and obstacles to such summary action. On motion it was resolved that a committee of five be appointed by the President to prepare and have in readiness material which might be used, if required, to oppose the compulsory introduction by law of the Metric System into America. The President at a later period appointed as such Committee, Messrs. Coleman Sellers, John E. Sweet, Chas. T. Porter, George M. Bond, and Coleman Sellers, Jr."

This action of the Council was reported to the Society at the next annual meeting, and is recorded on page 10 of vol. xviii. of the *Transactions*.

Since the appointment of this Committee, whose purpose was "to prepare and have in readiness" certain information, the Society has not heard from it and the data which it was requested to obtain have not yet been put on record in the archives. The Secretary of this Committee, however, has addressed the daily press as an officer of the Committee, making it appear thereby that The American Society of Mechanical Engineers as an organization was strongly opposed to the compulsory introduction of the Metric System.

This same member went before the Congressional Committee, to present his personal opinions about the hardships which the introduction of the Metric System would entail upon all manufacturers, and emphasized repeatedly that a long letter addressed to the Chairman of the Congressional Committee and written on the Society's letter-head was signed by the Secretary of the Society. This letter written by the Secretary of the Society upon its official paper and expressing opinions in opposition to the introduction of the Metric System, was by the above action made to appear as an official opinion of the Society, expressed by its Secretary, although signed by him as an individual and not as an officer.

It is an established principle of this Society neither to endorse, approve, nor recommend the action of its committees presented in their report. It is, furthermore, far beyond the scope of this Society to appoint committees for the purpose of affecting legislation. Nevertheless, the Secretary of this Committee stated before the Congressional Committee that this Society had adopted and approved the report of a committee recommending a decimal gauge as standard for dimensions of wire. It would appear, furthermore, that this Committee and the Secretary of the Society have tried to affect legislation by making it appear that this Society was strongly opposed to the introduction of the Metric System.

In view of the foregoing facts, it is my opinion that those members of the Metric Opposition Committee and all others who have taken part in this public agitation, should be requested to abstain from further public utterances and communications. For this reason I would beg leave to offer the following:

Resolved, That hereafter all committees and officers of the Society and of the Council shall present their reports to the Society or to its Council, for review and approval before publication; and further:

Resolved, That no member of the Society nor any officer thereof or of the Council shall attempt to represent the Society for any purpose whatsoever, without instructions from the Council or the Society.

I think it is time that the present Metric Opposition Committee be excused from further considering the subject before it, and that members be appointed thereon who are more in harmony with the customs and practices of this Society.

The resolution closing the communication was seconded by Mr. Forbes, and an amendment was offered by Mr. Miller, that it should read that "no member or officer of the Society shall undertake to represent the Society without authorization from the Society duly given."

Mr. Henning explained that the Council as a rule was supposed to represent the Society, and it was his preference that the resolution should remain in the shape proposed, so that in an emergency the Council might take prompt action on behalf of the Society without delaying to give opportunity for the Society to instruct the Council.

The motion in its original form was adopted.

The meeting then passed to the consideration of the professional papers and took up first the "Report of the Society's Committee on the Codification of Methods of Conducting Engine Tests."

Professor Jacobus as reporter of the Committee presented the form of the report as the Committee had digested it, together with certain discussions which had been received from various members in comment on the recommendations of the Committee.

Professor Jacobus referred with regret to the loss which the committee had experienced since the last Report of the Committee, in the lamented death of Mr. Bryan Donkin of England, who had taken very active interest in the work of the committee during all its deliberations.

Messrs. Heisler, Munroe, H. W. Spangler, Gaetano Lanza, Ball, Reeve, Morse, and Smart took part in the discussion, and the matter was referred back to the Committee to incorporate into its final report any suggestions and amendments which might come to the notice of the Committee before the annual meeting of the Society in New York.

A supplementary report from the Committee on the Standardization of the Proportions of Pipe Unions was presented by Mr. E. M. Herr, with a sketch of suggestions which have been offered to improve the design which was submitted at the New York meeting of 1901.

Messrs. Forbes, Suplee, and Nason took part in the discussion of the supplementary report. The Society took no action concerning the criticisms.

The morning had become so far advanced that, in view of the engagements for the afternoon, it had become impossible to take up the two remaining papers listed for the morning session, so on motion the Society took a recess with the understanding that these two papers would come up at the head of the list for the evening session.

Announcement were made by the Chairman of the Sub-committee in charge of the reception on Thursday evening, and the meeting adjourned for the luncheon served in the Institute building by the courtesy of the Local Committee. After luncheon the visitors were divided into small parties with competent guides, for a visit to the various departments of the educational activity of the Institute of Technology.

Third Session. Wednesday, May 28th, 8.30 p.m.

By unanimous consent, before calling the session to order for the presentation of the regular business of the evening, the courtesy of the floor was given to Lieut. Godfrey L. Carden of the United States Revenue Service, who gave some information concerning the relation of the Federal government to the fair to be held in 1904 in St. Louis, and the desire of the technical departments of the Federal government that the industrial achievements of the country should be creditably represented at this fair, and the arrangements which were making to attain this result. At the end of this brief presentation the Society was formally convened for the consideration of the evening's programme. The papers for the evening were: "Specifications for Steel Forgings, Castings, and Boiler Plates," by Wm. R. Webster; "Test of Steam-Pipe Coverings," by Mr. George H. Barrus; "Elevator Safeties," by Chas. R. Pratt; "Construction of Atlantic Avenue Power Station, Boston," by Messrs. I. E. Moultrop and R. E. Curtis; "Swivel Joint for High-Pressure Main," by R. E. Curtis; "De-

termining Temperatures of Exhaust Gases in Combustion Engines," and "Working Details of a Gas-Engine Test," by R. H. Fernald; "Liquid Fuel Combustion," by Chas. E. Lucke. The participants in debate were Messrs. S. M. Vauclain, G. C. Henning, H. H. Suplee, Gaetano Lanza, Crosby, D. S. Jacobus, Wm. Kent, H. W. Spangler, E. S. Farwell, Geo. Dinkel, W. H. Morse, and A. J. Frith.

Mr. Pratt presented his paper by means of lantern slides.

Fourth Session. Thursday, May 29th, 10.30 a.m.

The papers for the morning were as follows: "A Roller Extensometer," by Gus. C. Henning; "Mechanical Stokers for Locomotives," by Fred. H. Colvin; "Improved Indicator Cock for Engines," by A. K. Mansfield; "Electricity in Cotton Mills," by W. B. Smith Whaley; "Some Details of Direct-Connected Generator Sets," by Wm. J. Bryan; "A Graphical Determination of Piston Acceleration," by J. N. Le Conte. The participants in debate were Messrs. R. H. Soule, G. L. Fowler, J. M. Smith, C. P. Higgins, C. W. Barnaby, C. H. Benjamin, F. W. Dean, H. H. Suplee, W. D. Forbes, and Wm. Kent.

The members were invited on their way to the afternoon excursion to inspect the Atlantic Avenue Power Station of the Edison Electric Illuminating Company. Many, however, went directly to the steamer at Rowe's Wharf which conveyed the party to Downer's Landing, where trolley cars carried them within a short distance of the plant of the Fore River Ship and Engine Company. Luncheon was served on the boat by courtesy of the Local Committee.

At the plant of the company the party was escorted through the Forge Department, the Power House with its electric and pneumatic plant, and the Machine Shop, Yards, and Plating Departments.

In the yard were the torpedo boat destroyers "Lawrence" and "MacDonough," the cruiser "Des Moines," the battle-ships "New Jersey" and "Rhode Island," and the seven-masted schooner "Thomas W. Lawson." The party returned by trolley and boat to the city.

In the evening was held the important social affair of the meeting in the form of a reception to the Society in the Boston Museum

of Fine Arts, on Copley Square. The Museum authorities and the residents of Boston were represented by Mr. Samuel D. Warren, President of the Board of Trustees of the Museum, and Mrs. Warren. During the reception a most enjoyable orchestral rendering of selections was enjoyed, presented by members of the Symphony Orchestra.

A collation was served in a tent in the courtyard of the Museum. The treasures of the Museum collections were greatly enjoyed by the visitors.

Fifth Session. Friday Morning, May 30th.

By invitation of the President and Corporation of Harvard University, the closing session of the Society was convened in the large lecture hall of the Engineering Building, which is known as "Pierce Hall." In addition to the normal presentation of papers and discussion of the professional matters which they involved, the following matters of business were presented.

Pursuant to the resolution of Mr. Towne at the Wednesday session, the Chair was directed to appoint a committee of three who should be entrusted with the duty of nominating a committee of three to consider all questions relating to the revision of the Society's Constitution and By-Laws and Rules. Under the authority of that resolution the Chair had appointed Messrs. Ambrose Swasey, John T. Hawkins, and Wm. O. Webber as such Nominating Committee. This Committee retired and presented as its report the nomination of the following committee to consider the proposed amendments to the By-Laws, and present such revision as might seem desirable for the Society to consider. The report presented the names of Messrs. Charles Wallace Hunt, Henry R. Towne, and Jesse M. Smith.

On motion the nomination of the committee was confirmed and made the action of the Society.

The Chair called attention also to the fact that the provisions of the By-Laws now in force in Article 31, require an appointment at the spring meeting of a committee to prepare and present nominations for the offices in the Society falling vacant at the annual meeting. The Chair stated that while it was customary for this appointment to be made by the presiding officer at the closing session of the meeting, it would be his preference—inasmuch

as he was a temporary officer merely supplying the vacancy in the absence of the President—that this duty should be discharged by the President of the Society in his understanding with respect to the courtesies in the case. If he heard no objection from the meeting he would take this action and ask that the appointment might be made by the President of the Society at his convenience after the meeting had adjourned. No objection being made, this action stood.

The debate upon the paper of Mr. C. C. Tyler resulted in a resolution that there should be referred to the Council with power, the question of appointing a committee of five of the Society who should consider the question of formulating a standard for machine screw threads and machine screws. This motion being duly seconded was carried, and the matter referred to the Council.

The papers of the morning were as follows: "Technical Index and File," by R. H. Soule; "The Lowell Gaslight Company's Coal Pocket," by F. M. Bowman; "The Flying Shear," by V. E. Edwards; "Standards for Machine Screws," by C. C. Tyler; "Cold Working of Sheet Metals in Dies," by John D. Riggs; "Repairing a Broken Cylinder," by H. M. Lane. In the discussion on them the following members took part: Messrs. H. P. Quick, G. T. Voorhees, S. Whinery, H. H. Suplee, G. L. Fowler, H. M. Lane, Oberlin Smith, Jno. T. Hawkins, C. R. Gabriel, Geo. R. Stetson, Geo. M. Bond, Ambrose Swasey, F. H. Boyer, Jos. E. Lewis.

At the close of the professional discussions, under the provision concerning new business at this meeting, the Secretary read the following series of resolutions:

The American Society of Mechanical Engineers at the closing session of its most successful Boston meeting desires to put on record its sense of appreciation for all the courtesies and attentions which have been lavished upon the members during their stay. They would ask that in the somewhat formal mould of the resolution whereby a large number of persons seek to voice their sentiments, those who read will detect the earnestness of feeling which lies behind the words.

They would offer for action, therefore, the following resolutions:

Resolved, That the Society would desire to express to Dr. Henry Smith Pritchett and to the President and Board of Governors of the Massachusetts Institute of Technology their sincere thanks for the elaborate, complete and faultless arrangements at the Institute for the sessions of the meeting. To Dr. Pritchett they would speak specially in recognition of the cordiality and character of his address of welcome, and their regret that the pressure of other business during the week has precluded his also taking part by his presence at the

professional sessions. The Boston meeting will long be remembered for many reasons, and connected with these memories will be that of the relation of Dr. Pritchett to the success of the first evening of the Convention. To Professor Lanza, of the Institute, and to his gifted and energetic assistants the Society would express its thanks for the arrangements for the visit to the Institute Laboratories, and for the admirable and exhaustive arrangements in connection with the headquarters and the meeting room. If Dr Pritchett is to be remembered by the Society for what *he* has done to make the meeting a success, the staff of the Institute will be none the less remembered for the way in which the details have been carried out.

The American Society of Mechanical Engineers would ask that Mr. George A. Kimball, President of the Boston Society of Civil Engineers, would accept from the Society a sincere expression of its thanks for the cordial wording of his address of welcome. While it is true that year by year the profession of engineering is specializing, it is also none the less true that at bottom all engineering is one, and we ask that Mr. Kimball and his society will rest assured that in our recognizing the achievements with which he and his associates are identified, he is receiving the appreciative recognition of fellow craftsmen. They would ask that in all the proffer of service and courtesy, the Society and its President will feel assured of hearty appreciation.

Resolved, That in the action of the New England Telegraph and Telephone Company by its courtesy in putting at the service of the Society at headquarters a complimentary telephone service throughout New England, the Society recognizes a kindly feeling for which they seek in this way to give expression.

Resolved, That the thanks of the Society are extended to the American Telegraph and Telephone Company for the courtesy whereby the headquarters of the Society have been put in communication with the entire Long Distance service of the country, and that in putting this service at the disposal of the Society and its members during their stay, the Society has received a courtesy of unusual significance and for which their thanks are due and given.

In pleasant memory of the distinguished courtesy of the reception tendered to the Society in 1885 on the occasion of its last Boston meeting, the American Society of Mechanical Engineers would express to the Boston Art club its sincere thanks for the courtesy of the invitation so freely extended to its members to enjoy its treasures and the courtesies of its home during the continuance of the Boston meeting. The pressure of the other engagements of a somewhat mere formal character has prevented any considerable number from availing of this courtesy, but none the less is it heartily appreciated by its beneficiaries.

Resolved, That the thanks of the Society are extended to the Technology Club through Mr. James P. Monroe, its President, for the courtesy of being put up as visiting members of the Club during the days of their stay in Boston. It has been difficult to find room even edgewise for the social and personal courtesies which this invitation would have put in our way.

The Society would ask that the St. Botolph Club will accept from the Society the sincere thanks of that body for the courtesy whereby its members have been made officially members in enjoyment of the Club courtesies during the days of the meeting. The privilege of the house committee's invitation which they extended to the Local Committee of Arrangements of our meeting, has been most

heartily appreciated, and the membership at large can only regret that their previous arrangements and the full programme prevented their enjoying their courtesies which were extended by action of that body.

Resolved, That to the Fore River Ship and Engine Co. the Society extends its sincere thanks for the privilege of a visit to their plant on Thursday afternoon and an inspection of work in progress and of their facilities; it would extend to the Company it sincere wishes that on the foundation already laid a history of success and prosperity may rear as a superstructure upon which the Society may look with pride in its memory of the Boston meeting of 1902.

Resolved, That the thanks of the Society are due and extended to the Edison Electric Illuminating Co. for the courtesy of putting their power plant at the service of the Committee and the Society for a visit of inspection on Thursday afternoon.

The Society feels most strongly the limitations set by the somewhat formal character of the preamble and resolution when it seeks to express to a body such as the President and Trustees of the Museum of Fine Arts its recognition and appreciation of a courtesy of the unique and impressive sort which is involved in a reception such as was tendered to it on Thursday evening; that such a reception should be put within the reach of the Society; that in tendering it it should be made so intrinsically enjoyable by so many surrounding conditions of pleasure; that an opportunity should have been given to the Society in this way to meet representative citizens of Boston, make up a total of pleasure and of enjoyment for which best arranged sentences are but an unsatisfactory vehicle.

The Society asks that Mr. Saml. D. Warren, President of the Museum, and those associated with him will read in our resolution of sincere thanks a deeper feeling of the personal sort than is revealed by the reading of the lines themselves.

The thanks of the Society are extended to President Chas. W. Eliot, of Harvard University and the Fellows and Corporation of that great institution for the invitation to the Society that it should be the guests of Harvard for its closing session on Friday morning. They would ask further, that in providing for the entertainment of the Society at its Harvard visit and for the courtesy and distinguished consideration of the President's address, he will accept on his own behalf and that of his associates, a profound recogntion of all that such greetings carry with them of good feeling and kindly consideration.

When it comes to be the duty of husbands, brothers, and friends to make themselves the mouthpiece of the ladies of the Society in attendance at the Boston meeting, for an expression to the Committee of Boston Ladies for the unremitting, beautiful and successful attentions of which they have been the channel, the inadequacy of the mere man for a responsibility of this sort makes itself most keenly felt. From the very beginning in headquarters on Tuesday, through the drive on Wednesday, through the trolley ride and the boat trip on Thursday, and including the presence of these ladies on Friday, the Ladies' Committee has been unceasing in its attentions, and the plans for the entertainment of the visiting ladies have been so well laid and so successfully carried out that the memory of these entertainments will long form a bright spot in the recollections concerning the Boston meeting.

To Mrs. F. H. Boyer as Chairman of this Ladies' Committee and to those who co-operated with her, the ladies ask that the sincere thanks of that entire group may be poured forth through this channel in unstinted measure.

And last of all, it comes to the placing of the keystone in the arch of success. The Society has had some experience individually of what it means to be the responsible host of a Society Convention, but it has never been anybody's privilege to be the host for such a meeting as this. The Boston meeting would have been a success anyhow, but very much of the brilliancy of that success is due to the talent and unremitting assiduity of the Local Committee. It must be remembered, also, that there can be no more competent and kindly judges than Mechanical Engineers who are themselves familiar with what it means to carry large undertakings to a successful issue.

To Mr. Francis H. Boyer, Chairman of the Local Committee of Arrangements, and to the Chairmen of Sub-Committees and the General Committee, the Society would seek to convey by this last resolution the full measure of its appreciation for the success of a meeting which will doubtless long remain a distinguished and phenomenal event in the Society's history.

It is impossible to express adequately by a few brief words the full and enthusiastic delight of the visiting members and it is left to the individual assurance which each member is asked to give to convey to these gentlemen the full record of what we feel we owe to them.

Resolved, That the Secretary be directed to send copies of these resolutions to the persons to whom they refer in each case.

Resolved, That to the firms, corporations and individuals who have put their works or establishments at the service of the members of the Society for individual visits, the sincere thanks of the Society are extended and that the Secretary be requested to convey to such persons the sincere appreciation of the Society by a letter of recognition after the adjournment of the Convention.

After a short visit through the engineering building the members joined the ladies for luncheon served in the Memorial Hall. It had been the original purpose to serve this luncheon in the Harvard Union, but the size of the party, numbering over 600, to be taken care of, made it impossible to provide for them in any way, except in the large dining-hall of the University. President Eliot after the luncheon welcomed the Society to Harvard University, and acting-President Dodge made fitting response.

After luncheon the members separated to visit the museum collections and other points of interest in the University. Very complete maps had been furnished to the members and incorporated in their programme, whereby they could find the points of interest without difficulty.

For the entertainment of the visiting ladies during the Boston meeting, a large committee of resident ladies had been formed and special excursions were arranged under their guidance.

On Wednesday morning a ride in coaches had been provided, through the beautiful suburbs and part of the park system, with a luncheon at Woodland Park Hotel at Auburndale.

On Thursday morning the ladies were escorted in trolley cars over the lines of the trolley system of Boston, into the suburbs, the route bringing them to the boat at Rowe's Wharf to meet the members who had been at the professional session.

On Friday morning the ladies were invited to attend memorial services in Sanders Theatre of Harvard, in memory of the Harvard men who had died during the Civil War. These exercises are regular features of the Memorial Day at Harvard and are conducted by representatives of the student body.

In addition the Local Committee had made provision for individual visits to points of personal interest, outside of the provision made for the entertainment of the Society as a whole. These were listed upon the regular programme, but so attractive was the official programme that but a limited number of members were able to avail of these facilities provided for them by the Local Committee.

No. 932.*

MECHANICAL STOKERS FOR LOCOMOTIVES.†

BY FRED H. COLVIN, NEW YORK.
(Member of the Society.)

1. The rapid growth in the size of locomotives and the consequent increased consumption of fuel per hour have brought many of our railroads face to face with the problem of securing men to fire them satisfactorily, for the fireman has not increased in size and capacity as has the locomotive. The question of economy in coal consumption is secondary to that of keeping the steam pressure at or near the popping point in order to secure the maximum work from the engine.

The conditions of locomotive practice are so different from those presented in the case of stokers for stationary boilers that they have seemed almost insurmountable, although much time and thought have been spent on them. These difficulties are not confined to the mechanical problem, for the selling of the locomotive stoker is an entirely different proposition from that in the stationary field. In the latter case it is an easy matter to show a marked reduction in labor cost, and this saving seems to appeal to buyers more than any other. In the case of the locomotive stoker there can be no reduction in labor cost, excepting in a few rare cases where two firemen are employed. This takes the cost of labor entirely out of the field, as it is not advisable to employ unskilled men on the locomotive equipped with a stoker, for in the event of the possible failure of the machine, the engine must be fired by hand until the end of the run. It is also necessary to train engineers, and the only practical way of doing this seems to be by having firemen work with engineers as at present.

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* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of volume xxiii. of the *Transactions*.

† For further references on the same subject, see *Transactions* as follows:
Vol xii., p. 921 : "Mechanical Stokers." W. R. Roney.
Vol. xvii., p. 278 : "Topical Discussions."
" " p. 558 : "Experiments with Automatic Mechanical Stokers." J. M. Whitham.

2. The practical advantages of the locomotive stoker can, perhaps, be summed up as follows:

Increased work from the locomotive, due to maintaining a maximum working steam pressure under all conditions of service.

Doing away with the necessity of constantly opening the fire door and admitting large quantities of cold air into the fire box, which opening tends to retard combustion and also has an injurious effect on the flue sheet.

Even distribution of coal over the whole of the grate, obviating thin spots through which cold air may be admitted with results as injurious as when coming through the door, or even more so.

Marked decrease in black smoke, due to the constant and steady firing according to the demands of the boiler.

Economy of coal consumption, resulting from the steady firing above referred to.

3. As the only stoker for locomotive use of which I know is the one invented by Mr. John W. Kincaid, of Cincinnati, Ohio, formerly an engineer on the Chesapeake and Ohio Railroad, my paper will necessarily be confined to this machine and its work. Starting with the idea of producing a mechanical stoker which should take the place of hand firing, and realizing the difficulty of introducing or even experimenting with a stoker which would necessitate any radical change in the locomotive, Mr. Kincaid designed his stoker to be attached in place of the fire door. It will be noticed that it is a mechanical but not an automatic stoker, as the experience of the practical engineer showed that it was not feasible to attempt automatic stoking. While it is possible that ingenious mechanism might be devised which would regulate the amount of coal fired by the steam pressure in the boiler, it would greatly complicate matters, and hardly be as effective as though under control of a skilled fireman. There are many cases, such as preparing for a hard pull up hill, where the fireman will anticipate the demand on the boiler and prepare for it, while an automatic device must follow the demand instead of anticipating it.

The Kincaid stoker is fastened to the fire door opening, as will be seen from the illustrations, Figs. 163-165, and consists of the hopper *A*, ram body *B*, ram cylinder *C*, steam chest *D*, door frame *E*, conveyer cylinder *F*, its valve chest *H*, and the ram *b*. The conveying screws are actuated by the piston in cylinder *F*, which travels up and down and operates the screws by the ratchets shown, Fig. 163.

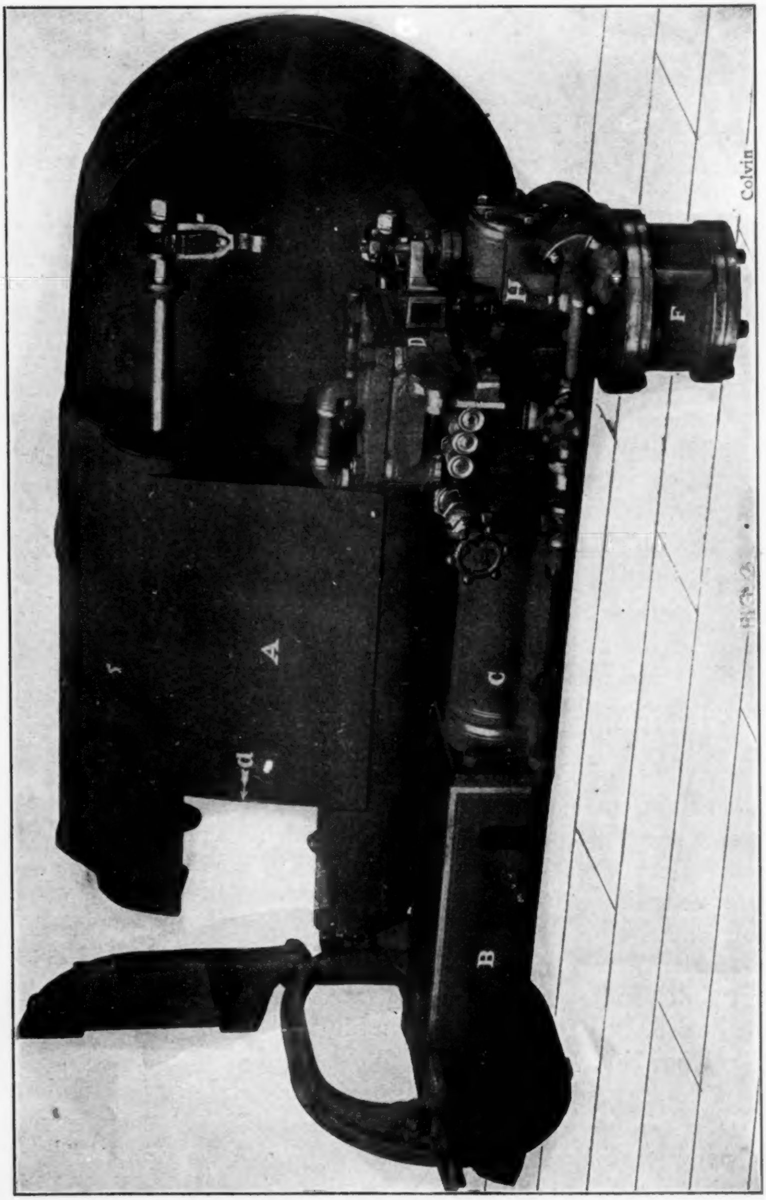

Fig. 163.—Left Side of Stoker with Hopper Thrown up.

The amount of coal fed forward to the ram can be varied by regulating the amount of steam by a globe valve near the valve chest *H*, and it can also be reduced one-half by throwing one of the screws out of gear.

4. A globe valve admits steam to the valve chest of the ram. The motion of this ram is controlled by an ingenious valve, which gives three different strokes in regular order. The first stroke takes a full charge of steam and throws the coal to the front end of the fire box; next comes a medium stroke which takes care of the middle portion, and lastly, a stroke which hardly does more

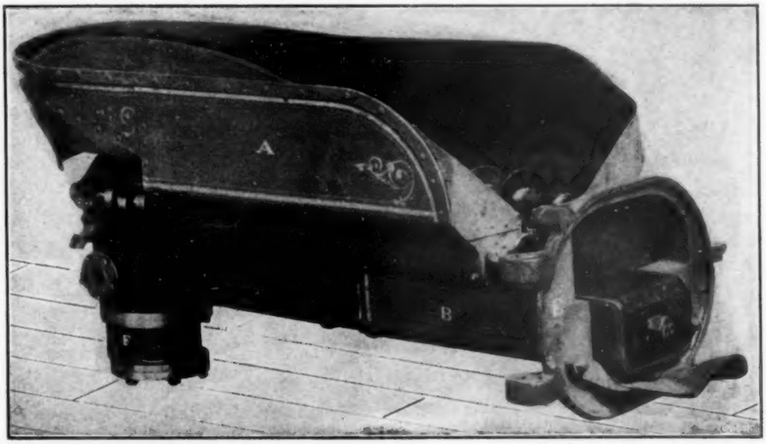

FIG. 164.—STOKER READY TO ATTACH, SHOWING RAM *B*. DOOR CASTING *E* AND DEFLECTOR PLATE.

than push the coal over the deflector plate, which is shown bolted to *B*.

It is sometimes asked how this action distributes the coal across the fire box, but the explanation is not difficult when we note that the exhaust from the ram cylinder passes along under the ram and goes over the deflector. It is an ingenious arrangement, and required considerable experimenting to secure the right shape for this plate. Mr. Kincaid tells me that during his experimenting he found certain shapes of deflector plates which would throw nearly all the coal along the sides of the box, and other shapes which would pile it up in the back corner. Any one familiar with the intense draught in a locomotive fire box would naturally credit this with a tendency to assist in the distribution, but I am

informed that one of the first machines gave equally good results in a small electric-light plant, where the draught was due only to a chimney..

5. That the distribution is practically perfect is proved by the fact that one of these machines has successfully fired several of the largest engines on the Chesapeake and Ohio Railroad in which the fire box was 41 inches wide and 11 feet long. It was my privilege to spend a day on one of these locomotives a little over a year ago, and in a nine-hour run the hook was used but three times. It is probable that even this would have been unnecessary

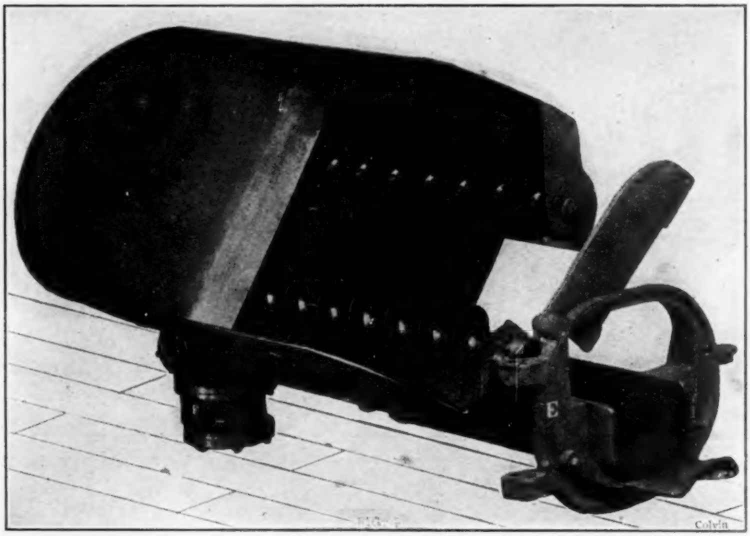

FIG. 165.—TOP VIEW, SHOWING CONVEYING SCREWS AND AUXILIARY FIRE-DOOR.

but for the firing done at various stopping points to show the working of the machine to men who came on the engine. This rather clogged the fire and necessitated opening it up with the hook.

6. As an illustration of the range of capacity of this machine, it is interesting to note that the same stoker which fired the engine just referred to in my trip from Hinton, W. Va., over the mountains to Clifton Forge, Va., had been previously used on one of the lightest passenger engines on the division. Climbing some of the hardest grades over the mountains the stoker was speeded up to 18 strokes per minute; and as the average charge was 5 or 6 pounds, this gave from 90 to 108 pounds per minute, or from

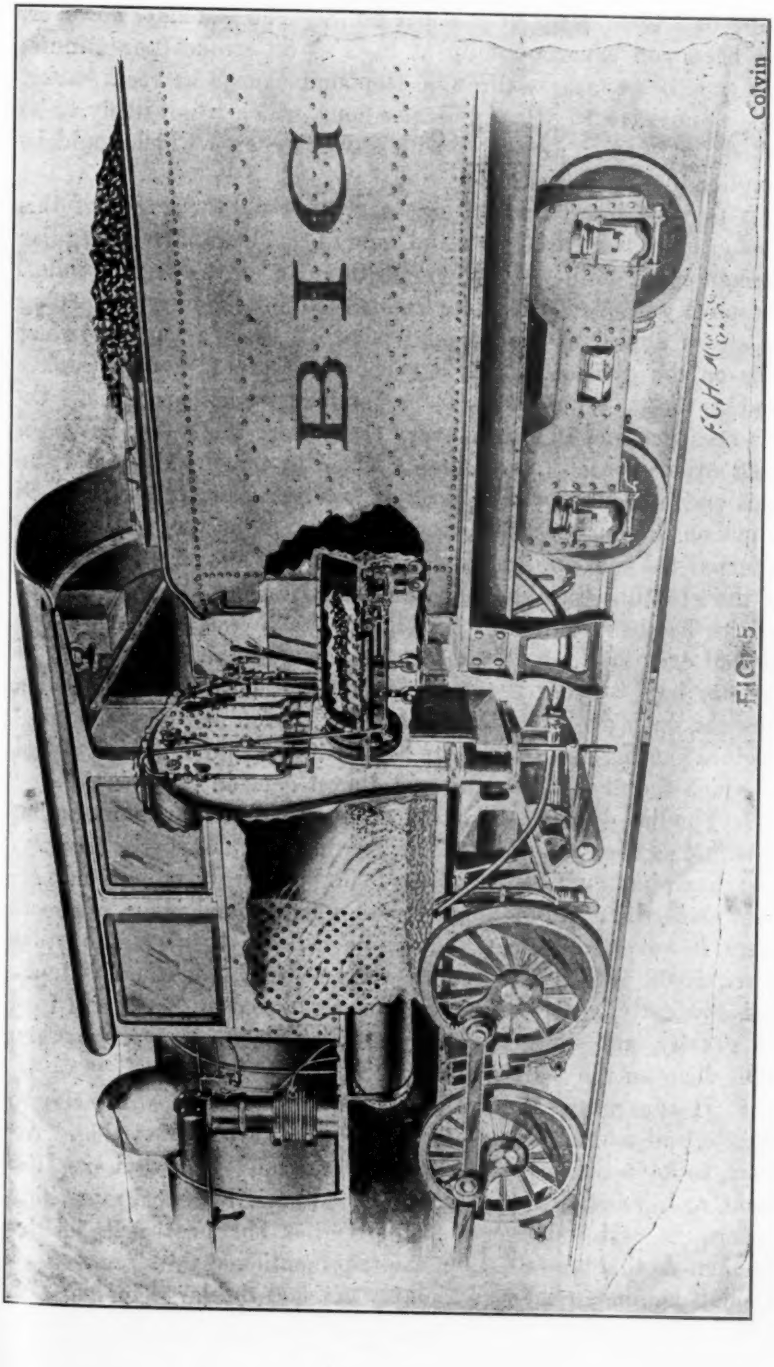

FIG. 166—STOKER ATTACHED TO BIG FOUR FREIGHT ENGINE.

5,400 to 6,480 pounds of coal per hour. The machine, however, has been run experimentally as high as 28 strokes per minute, and can, if necessary, throw a 10-pound charge at each stroke. This would give 16,800 pounds per hour, which is not likely to be called for in any practice or with any grate area which could be supplied by this machine.

It may be interesting to note that on the return trip of this locomotive it was fired by hand, and in spite of all the regular fireman could do, he lost 50 pounds of steam in the first 12 miles. On the day previous this same fireman had no difficulty in keeping up steam almost to the popping point all the way up the worst hills on the division. This is self-evident proof that the stoker enables the maximum work to be obtained from the engine. On this occasion, and in almost every case where the stoker has been tried experimentally, it is simply fitted to the fire door and the back end braced up with a block of wood, or possibly a false deck is put on the engine. This was the case on the large locomotive referred to, and the fireman was obliged to shovel every pound of the coal into the hopper, which was thus at an inconvenient height, but in spite of this he told me that it was the easiest trip he had ever fired, as he was not subjected to the intense heat of the fire box at every shovelful. Only those who have stood before the open door of a locomotive fire box on one of these large engines hauling its full tonnage behind it can appreciate the ordeal to which the fireman is subjected almost constantly.

7. The line drawing, Fig. 167, shows how a standard tank can be modified so that the coal will be fed into the hopper by gravity, and the fireman will have nothing to do but run the stoker and perhaps assist the coal occasionally with a small hand rake. In most cases, however, the jar of the engine will do all the feeding that is required. Fig. 168 shows a conveyor fitted to a standard tank. It is evidently better, however, to have the coal so that it will feed by gravity, and there is no objection to placing it well forward as is done on the Vanderbilt tender.

8. It apparently handles any kind of fuel from anthracite to lignite, and ranging from lump coal to slack. It is advisable, however, to have the coal broken to approximately uniform size, the same as in hand firing. On some roads this is done by machine before the coal is delivered to the engine, but most roads let the fireman do this himself. On the trip mentioned the fireman kept a small hammer ready, and simply cracked the large lumps. If

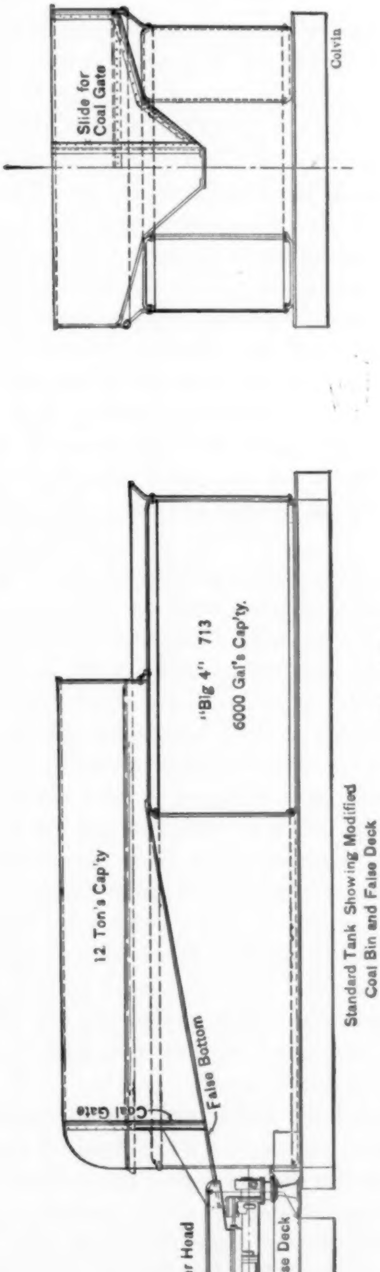
Slide for Coal Gate
Colvin
12 Ton's Cap'ty
"Big 4" 713
6000 Gal's Cap'ty.
Coal Gate
False Bottom
Boiler Head
False Deck
Standard Tank Showing Modified Coal Bin and False Deck

FIG. 167.

however, a lump larger than the size of the ram should get into the hopper and be caught by the ram it would lift the auxiliary fire door, which has an angle apron or lip for this purpose. This door is large enough to open for examination of the fire from time to time, or for using the hook if necessary, and in fact is as large as the opening of some of the fire doors used on a few of the Western mountain roads. With the hopper tipped back as shown, the locomotive could be fired by hand through this opening, but it is not necessary, as it is a simple matter to disconnect the steam pipe and swing the whole stoker to one side or even unhook it entirely. One of the engineers of the famous "F. F. V." train on the Chesapeake and Ohio Railroad told me of his experience with one of the first machines. A defective casting gave way when they were running at full speed, and the fireman disconnected the stoker, swung it out of the way, and commenced firing by hand, without delaying him an instant or even causing him to ease up on the throttle.

9. I regret that I am unable to present any data as to the exact performance of these stokers, such as fuel economy, prevention of smoke, prevention of leaky flues, and increase in tonnage, due to their use. I can, however, testify to the practical working of the device from actual experience, and am informed by Mr. W. S. Morris, Superintendent of the Chesapeake and Ohio Railroad, and other officials, that there is a marked advantage over hand firing. Some of the reports have credited it with a saving of 10 or 20 per cent. in fuel, but this is an estimate and not the result of careful test. It seems, however, that there should be no question as to some saving due to constant, regular firing.

Others inform me that it does away with nine-tenths of the black smoke nuisance, while still others reduce this to 75 per cent. With dampened coal (and without this, I believe, it is impossible to secure smokeless firing with any device, as the fine particles are drawn up the stack before they can ignite) there should be a marked decrease in black smoke.

10. One road tried the stoker only on an engine which leaked so badly that it could not be run when fired by hand. It did run with the stoker, but this did not repair the engine, for, as Mr. Kincaid said, it was a stoker and not a flue caulker.

While up to the present time the work with the stoker has been largely experimental, it is but fair to give great credit to Mr. J. H. Day, a well-known manufacturer of Cincinnati, for his fore-

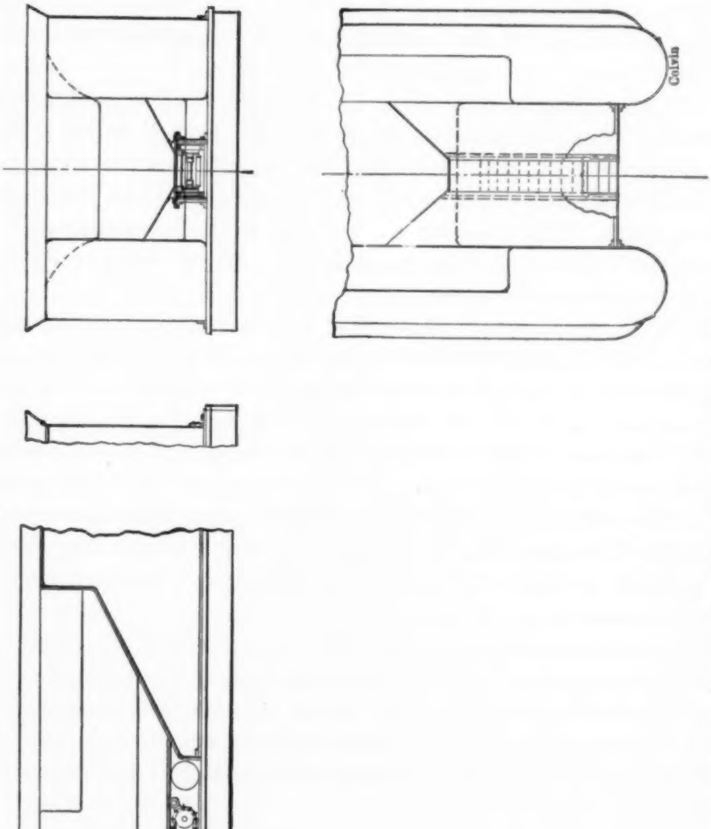

FIG. 168.—CONVEYOR FITTED TO A STANDARD TANK.

sight and persistency in making it possible for Mr. Kincaid to devote his time to this invention. There is now no doubt as to the machine being thoroughly practical, and it is quite probable that within the course of a few months it will be manufactured on the scale it deserves.

11. Although primarily designed for a locomotive stoker it is admirably adapted for marine work with the Scotch boiler. The fact of requiring no special setting, but being attachable to almost any boiler without alteration is sure to appeal to the man who pays the bills, as in case it should not meet all the requirements, there is no expense or delay in taking out the device and substituting those formerly used.

Up to the present time the stoker has been applied to what is known as the narrow fire box locomotive, but it requires simply a modification in design, and probably a little experimenting into the bargain, to adapt it for wider boxes. In the so-called Wooten fire box, which in a few extreme cases is 9 feet 6 inches wide, it would probably require two machines, one for each door. But in view of the fact that the extremely large grate is not well adapted to burning bituminous coal, and that within a few years this is likely to be the only fuel for locomotives, this can hardly be called much of an obstacle.

Another locomotive stoker has been submitted to me recently, on the plan of one of the under-feed stationary stokers, but as it necessitates extensive alterations in the fire box before applying I do not see how it is to make much headway against a device like the Kincaid, which can be attached with practically no change or expense.

DISCUSSION.

Mr. R. H. Soule.—As this is a novelty, for although mechanical stokers are common enough, yet their application to locomotives is certainly a novelty, it is difficult to judge of the efficiency of the mechanism. But I think there are plenty of evidences that there is a large field for a mechanical stoker on a locomotive. Last December, Professor Goss, one of our own members, read a very excellent paper before the New England Railroad Club, in Boston, called "Some Factors Affecting the Power of Locomotives," in which he developed a plan for laying out the horse-power curve of any locomotive from which you could

read directly the tractive power due to any speed, and he also laid out certain parallel curves resulting from deductions from useful effort in the cylinders; these deductions were, first, the internal friction of the engine; second, the wind resistance; and third, the resistance of the rolling load of the engine itself outside of the internal friction; this paper was very widely distributed and reported by the technical press and brought out a number of letters and comments on it. One of them was from a professor of one of the Western technical colleges, who had a number of records of the actual performance of locomotives, which he charted to compare them with Professor Goss's curves, and showed, as he stated in a letter to the "Railroad Gazette," that the curve of performance of these locomotives which he had charted in every case fell below Professor Goss's minimum curve, which raised a question in his mind whether there was not some mistake in Professor Goss's assumptions or conclusions. I happened to meet Professor Goss soon after that, and asked him if he was going to answer this communication and how, and he said at once that the answer was very simple indeed; the evidence was plain that these locomotives which had been charted by the Western correspondent were not worked up to their maximum performance, and that his (Professor Goss's) curves showed, or were meant to show, the maximum performance of a locomotive based on its horse-power capacity, that, in turn, being based on its heating capacity. It is very evident to those who have followed up the development of the locomotive that we have about reached the capacity of the human fireman to shovel horse-power into the fire box at as rapid a rate as is necessary in order to get the maximum work out of the locomotive, and it seems to me that we are driven up to the wall, or very close to it, in that matter, and will have to depend, sooner or later, on mechanical stokers for locomotives if we are going on increasing their capacity the way that we have been doing in the last few years.

Mr. George L. Fowler.—I happened to see this stoker on exhibition about a year ago. They had one at Saratoga at the Master Mechanics' Convention, and it throws the coal out and distributes it very evenly over the fire. But there is some little difficulty in getting the coal into the back corners of the fire box close to the back head. It comes quite close, but at the same time the coal which is set into the corners, as I saw the machine at work, is dependent upon getting a little elevation and the coal going down

the slope by gravity. That, of course, is very apt to make a hole at the back of the fire box, but at the front end the coal is distributed very evenly. At the same time, there is the same trouble which the fireman is apt to experience in the front end of an engine, so that he usually throws an extra shovelful up into the corners in order to prevent the blast from drawing a hole through the fire at that point. In regard to the actual working of this stoker, it was in use on the Chesapeake and Ohio road for about two years and a half, and it has given very satisfactory service. But the demand for mechanical stokers is, of course, only on very heavy engines drawing heavy trains; as Mr. Soule has said, the heavy engines which have recently been built and put on our trunk lines are beyond the capacity of ordinary firemen, and it has been found on quite a number of roads that they are not getting the calculated work out of the engine which they expected. The firemen simply cannot shovel coal into the fire box fast enough to do the work which the engine is capable of doing, and of course there is objection to assigning two firemen for the work from the standpoint of expense and also because there would be continual quarreling between the two men as to who should do the shoveling, and that is really one of the serious objections to the proposition. This stoker, if it is developed along the lines on which it now promises, will probably take the place of the two men, although there will have to be a skilled man to do the work, and I know several instances where they contemplate putting this stoker on mountain work in order to bring the engine up to its true and calculated capacity.

Mr. Jesse M. Smith.—Will the gentleman tell us how the coal is thrown into the rear? Does the piston move quickly or slowly?

Mr. Fowler.—It moves quickly. It is shot out as from a catapult, just as quickly as a piston can be moved. It strikes a shield at the front and is spread out over the fire in practically the same way in which a skilled fireman will give a twist to the shovel just as the coal leaves it and throw it in a shower on the fire. It comes down in a shower, and, as the paper says, it is scattered over the front end, then a short stroke throws it along the middle, and a still shorter stroke throws it along the back. But the main trouble is in getting it in the back corners so that there will not be a hole blown through the fire.

Mr. C. P. Higgins.—I would like to ask if there is any provision made in this stoking device for cleaning the fire. My obser-

vation has been that that is something which needs to be looked after in mechanical stokers—that there should be some definite method of cleaning. Is there anybody who can give us any information on this point?

Mr. Fowler.—The fire can be cleaned the same as an ordinary hand fire. The stoker is swung on a swivel, and if it is necessary to clean the fire at the top and haul out the clinkers it can be done. Of course, shaking the grates and cleaning underneath is accomplished in the usual way with the stoker in position. One of the great advantages of the stoker is that it keeps the door shut and avoids the continual draught of cold air striking against the tubes while firing. Again, with this, as with any other mechanical stoker, there is less smoke produced. The engines run, I am told, very nearly without any smoke whatever. Of course that does not mean so that you cannot see anything coming out of the stack, but it is good, smokeless combustion, as the term is generally understood.

No. 933.*

THE FLYING SHEAR.

BY V. E. EDWARDS, WORCESTER, MASS.
(Member of the Society.)

1. In the engineering office of a past president of this Society the question of cutting metal bars while in motion had been so carefully discussed that in 1892 a carte blanche order was accepted for a mill and equipment which should accomplish unprecedented results. The problem was to take two and one-half ton ingots after they had been worked down on a 34-inch reversing mill to a long bloom having a cross section of 4 inches by 5 inches, crop the first end of the piece which was then some 80 feet in length, roll the entire ingot to a section 1½ inches square, cut it up into any desired lengths from 15 to 30 feet, cool the severed billets and load them on cars. The stipulated crop waste was one crop and one short from the 4 inches by 5 inches bloom. This meant rolling a 1½ inch square section over 600 feet long and cutting it into 20 or more billets 30 feet long, or shorter if desired.

2. The ground available was a triangular space scarcely 100 feet on its longest side. Within this 100 feet must be placed the connecting drawbridge table, the preliminary shear, the mill, the finishing shear, and the elevator for taking the severed billets to a high overhead conveyor, which should carry them to a distant elevated cooling bed, from which they would be loaded on cars, by gravity. These conditions, of course, called for a continuous mill and meant that the billets must be cut while in motion and close to the finishing pass.

3. The mill problem was interesting. The shear problem had in addition the exhilaration of pioneer work. The preliminary shear must be able to cut 4 inches by 5 inches hot steel, and to do this cutting while the bloom was either stationary or in motion. The shear used is clearly shown in Figs. 169 and 173. This is a

* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

simple hydraulic shear trunnioned at the base to permit the knives to travel with the moving bloom during the instant of cutting.

The shear at the finishing end of the mill required much study.

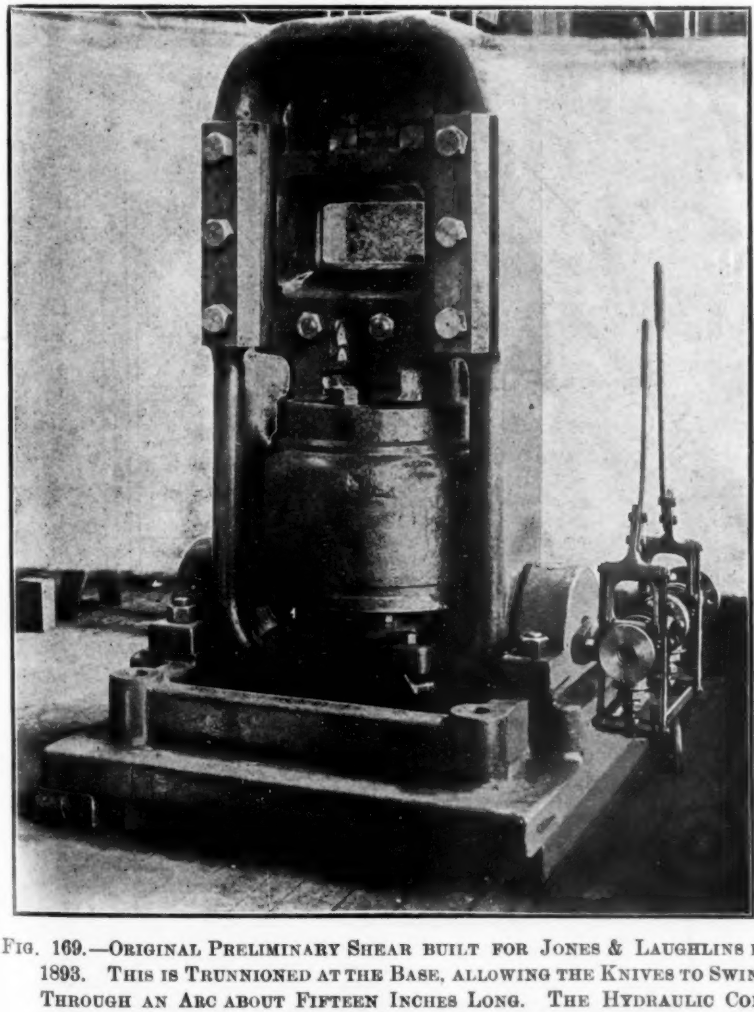

FIG. 169.—ORIGINAL PRELIMINARY SHEAR BUILT FOR JONES & LAUGHLINS IN 1893. THIS IS TRUNNIONED AT THE BASE, ALLOWING THE KNIVES TO SWING THROUGH AN ARC ABOUT FIFTEEN INCHES LONG. THE HYDRAULIC CONNECTION IS MADE THROUGH THE TRUNNION, AS IS CLEARLY SHOWN. THE RETURN STROKE ON THIS SHEAR WAS MADE BY GRAVITY.

The shear knives must move horizontally as fast as or a little faster than the billet. This horizontal movement must be entirely independent of the billet. The cutting must be done in a small frac-

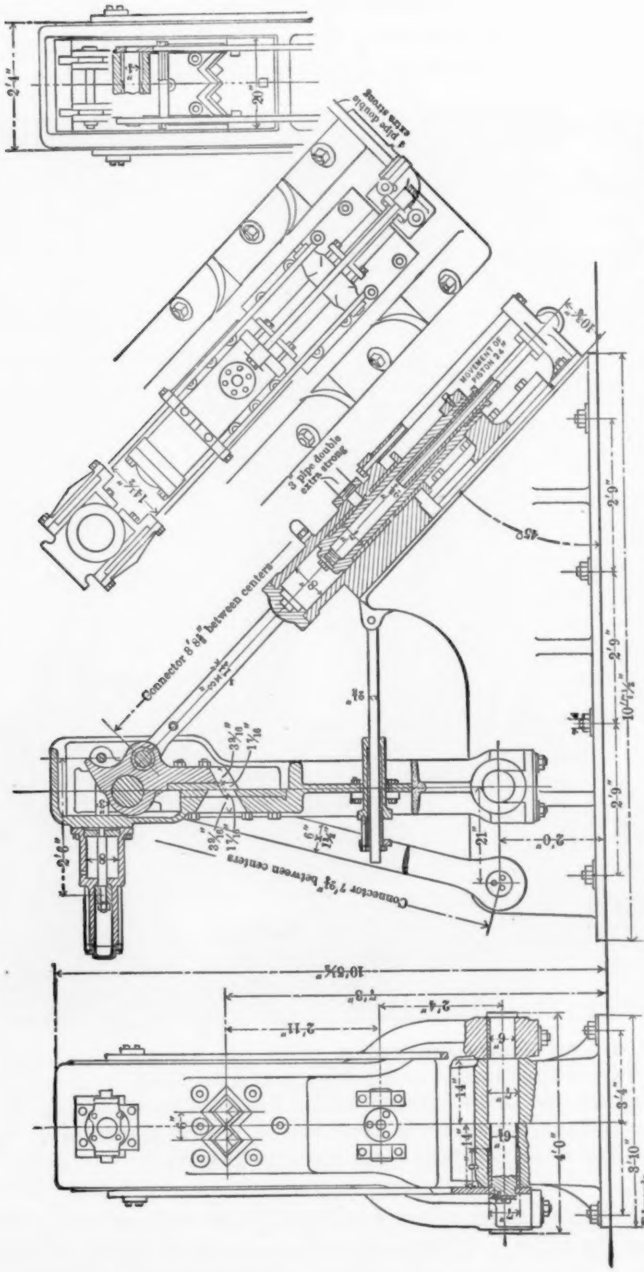

FIG. 170.—SECTIONAL ELEVATION OF ORIGINAL FLYING SHEAR YET IN USE BY JONES & LAUGHLINS.

tion of a second; a clear passage must be made instantly for the oncoming billet; the shear must complete its cycle and be back in its original position ready for the second cut, all in less than one second. The moving parts could not be made light, as the shear was to cut not only 1½ inches square, but any size up to 9 square

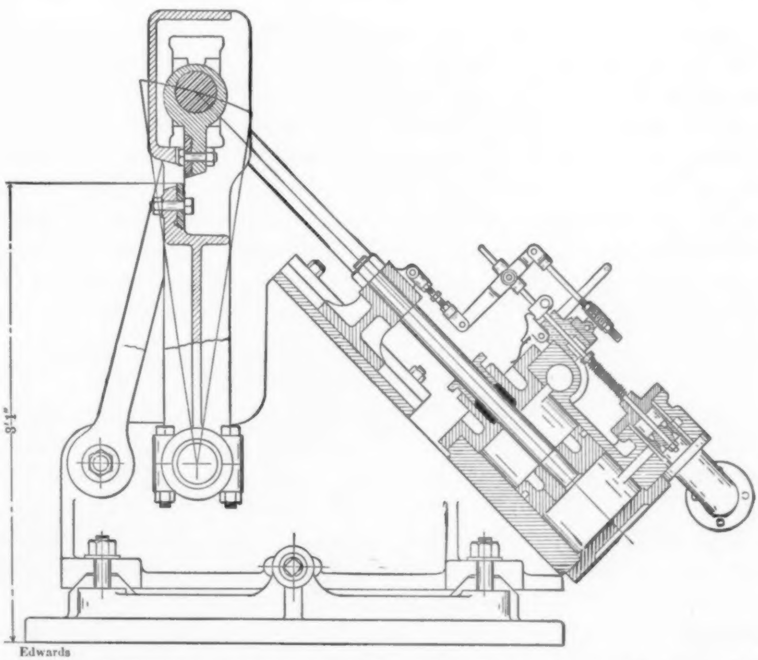

FIG. 171.—SECTIONAL ELEVATION OF ORIGINAL SMALL FLYING SHEAR. THE UPPER KNIFE IS FREE TO SWING ABOUT THE LARGE CROSS-HEAD PIN. THIS PIN HAS A COMBINED HORIZONTAL AND VERTICAL MOTION, AS INDICATED BY CURVED LINE.

inches section, and the steel was liable to be high carbon and quite cool.

4. From many designs, that shown in Fig. 170 was chosen. Fig. 171 shows the elementary idea more clearly. The two most noticeable features of this design are, first, the cutting is incidental to the forward movement of the shear; second, one knife is hinged in such a manner as to swing freely out of the way of the oncoming billet as soon as the cut is completed. The cutting stroke is made by a hydraulic cylinder in connection with a steam intensifier.

As the first end of the advancing billet passes between the knives to crop the first end, an attendant presses a small lever. This releases the steam pilot valve, which in turn opens the main steam valve. The steam piston rises, forcing the confined water into the shear-operating cylinder. The stroke of the cylinder is 24 inches. Of this 24-inch stroke, about 8 inches are used in picking up the clearance and in getting the shear knives to travelling as fast as the billet. About 8-inch stroke is used for the actual cutting, and the remaining 8 inches are used for clearance and for stopping the moving parts. The instant the shear begins to slow, the oncoming billet quietly pushes the hinged upper knife out of its path. Automatic link connections reverse the steam valves, and the return stroke is made by means of a small plunger under constant hydraulic pressure. The upper knife swings back to its original position while the return stroke is being made. The swinging knife is so heavy that a dash pot is used to prevent slamming.

5. After cropping the first end, all subsequent cuts are made automatically by the advancing end of the billet passing under a trigger placed 30 feet from the shear, or closer if shorter lengths are wanted. The first machine was a complete success, and has been in constant use about nine years, with only ordinary repairs.

The next shear of this type was a small one, for cropping the first end of bars while running between consecutive passes of a continuous mill and for cutting and diverting the bar in case of a cobble. See Figs. 171 and 172. This is operated by a boy, who snaps the trigger of the small piston valve of the operating steam cylinder. Quite a number of these have been installed, and they have become an important adjunct in rod, hoop, and merchant mills. The original shear of this size has been at work continuously for some seven years.

6. The billet mill and shear gave Jones & Laughlins such complete satisfaction that the Carnegie Steel Co. ordered a similar equipment to be used as an outlet for small billets from their 21-inch mills at Duquesne. To operate this shear, a direct-connected steam cylinder was used somewhat similar to the small shear which had given such good results. See Fig. 173. The success of this installation resulted in the Carnegie Co. placing an order for a second mill and shear for finishing the output of their new 40-inch mill at Duquesne. About the same time the National Steel Co. ordered a similar equipment for their "Ohio" plant at

Youngstown. More recently the Republic Iron and Steel Co. have ordered five shears for their new plant in the same busy city. The shear at the " Ohio " plant is the fastest running billet shear as yet installed; it is regularly cutting $1\frac{1}{2}$-inch steel billets at a rate of 2,000 tons per 24 hours, provided the mill is kept full.

Very high speed work calls for different treatment. In 1894

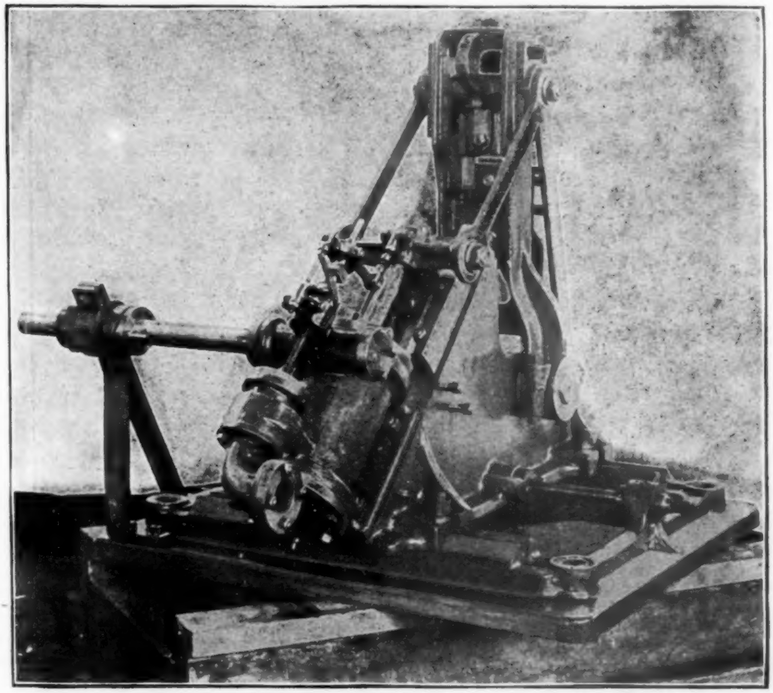

FIG. 172.—ORIGINAL SMALL FLYING SHEAR AS INSTALLED BETWEEN PASSES OF THE FIRST CONTINUOUS COTTON-TIE MILL AND SINCE ADOPTED AS AN IMPORTANT ADJUNCT TO CONTINUOUS ROD MILLS FOR CROPPING THE FIRST END OF BARS BETWEEN THE ROUGHING AND FINISHING PARTS OF THE MILL.

the Union Iron and Steel Co. of Youngstown, Ohio, placed a blanket contract for equipment to roll cotton-tie from a billet weighing 225 pounds (the common practice in rolling ties at that time was to use a billet weighing 15 pounds). In this mill everything was without precedent, continuous furnace, continuous roll trains, continuous shearing, and continuous cooling. It is needless to say that much trouble was experienced. Perhaps the most serious and expensive annoyance was the discouragement of the

workmen by their doubting and pessimistic friends. In this mill it was necessary to cut hot cotton tie seven-eighths of an inch in width by five one-hundredths of an inch in thickness, and to do this cutting while the hot tie was travelling at a speed of some 25 feet per second. The cutting in itself did not give much

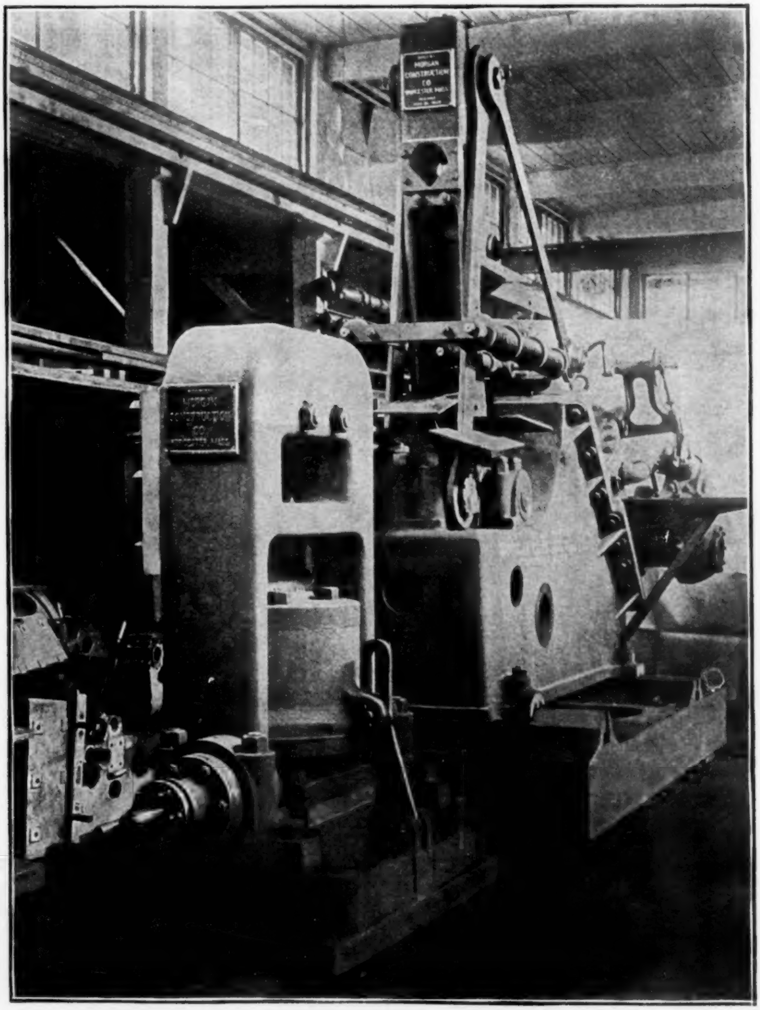

FIG. 173.—FIRST PRELIMINARY AND FLYING SHEARS BUILT FOR CARNEGIE STEEL CO. ON THE PRELIMINARY SHEAR IS SEEN THE SIMPLE LOST MOTION LINK, BY AID OF WHICH GRAVITY RETURNS THE SHEAR TO ITS UPRIGHT POSITION, AFTER BEING TILETD OVER BY THE BLOOM MOVING WHILE BEING CUT.

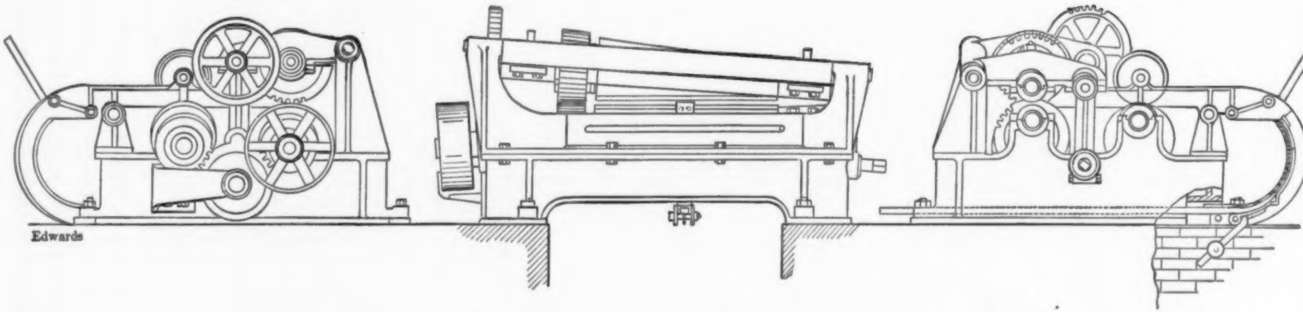

Fig. 174.—Conical Rotary Shear Used for Cutting Hot Cotton-Tie direct from the Finishing Pass. The Right-hand Elevation clearly shows the Upper Knife Drum Adjustably Controlled to Cut only on Multiple Revolutions.

trouble, neither did falling from the roof injure our traditional Irish friend. In both cases the trouble all came in the stopping.

7. Think of having some 150 hot, limber cotton-ties, 11 feet 6 inches long, limp almost as wet tissue paper, shot out endwise in one minute with no clearance between the ends. The momentum would slide them over 20 to 40 feet of rough iron floor. Let the least obstruction get in the way and a large pile of scrap was instantly made. These difficulties, however, were soon overcome, and the arrangements used gave excellent satisfaction for cotton-tie.

The shear used is shown in Fig. 174. The knives were carried on two conical drums geared together. In order to get long lengths without having large drums, small drums were used with the upper one carried in a hinged frame, the free end of this frame was supported through connecting rods by eccentrics on a shaft which was driven at one-half, one-third, or one-fourth of the number of the revolutions of the drum. By this means the knives did not quite meet, and consequently did not cut the thin tie except on multiple revolutions. By shifting the position of the knives on the cone, and by the use of change gears on the eccentric shaft, any length desired could be cut accurately.

8. For barrel hoop it appeared desirable to cool the hoop before allowing the severed strips to overlap, otherwise the hoop would look streaked and not have the beautiful blue finish acquired by uniform cooling with free exposure to the air. It was also desirable to be able to carry stocks in coils from which small orders could be shipped promptly, cut to any specified length. These conditions led to air-cooling the hoop by looping it out on an advancing apron and then reeling or coiling the hoop as it was delivered at the far end of the apron after it was sufficiently cool to have acquired and to hold its finish. These tightly wound coils were then either placed in stock or cut up at once on shears entirely apart from any interdependence with the rolling.

The shears shrown in Figs. 175 and 176 were quite compact and readily adjustable. The leading feature of these shears is the simple method of getting rotary shears to cut long lengths without complication or large diameters. This was accomplished by making the pitch diameter of the upper and lower cutting heads, together with their gearing, of different diameters. For example: If the gears have the ratio of 4 to 3, it will be seen that the knives would come in opposition but once in 3 revolutions of the large

head, or 4 revolutions of the small head; this allows the diameter of the cutting heads and gears to be reduced in the same proportion.

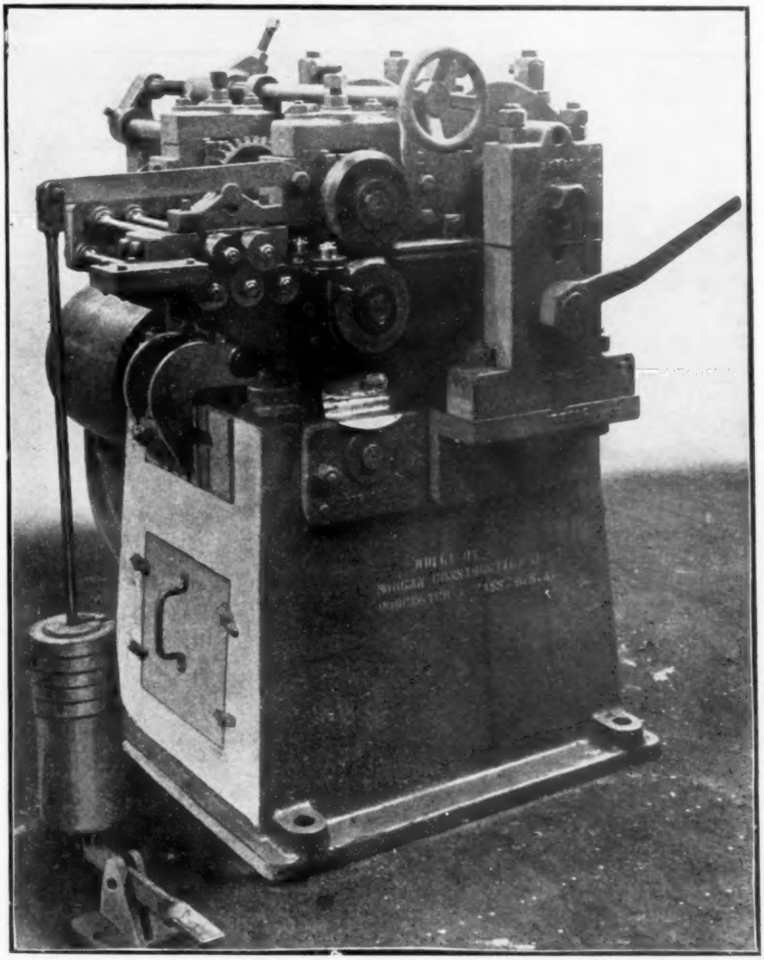

FIG. 175.—FRONT VIEW OF DIFFERENTIAL ROTARY FLYING SHEAR FOR EITHER HOT OR COLD HIGH SPEED CUTTING.

9. Cutting up material while in motion is not broadly new. We are all familiar with many appliances for this work, ranging from the old hay or feed cutter to that imposing organization, the modern newspaper press. Cutting metal bars while in motion

had been accomplished, for example, in rolling horse shoes and some other lines. Yet, considering the state of the art at that time, much credit is due Messrs. Jones & Laughlins for the firm confidence with which they installed an expensive and

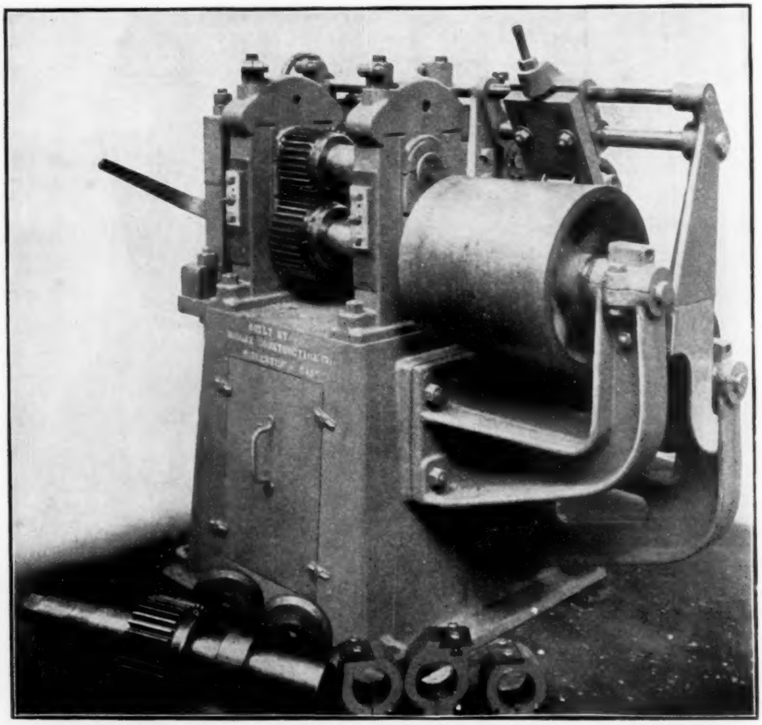

FIG. 176.—REAR VIEW OF DIFFERENTIAL ROTARY FLYING SHEAR. NOTE DIFFERENCE IN DIAMETER OF GEARS AND OF CUTTER HEADS ON FLOOR.

elaborate continuous mill and accessories while fully realizing that the success or failure of the whole equipment was entirely dependent on something so little demonstrated at that time as the Flying Shear.

No. 934.*

A SWIVELLING JOINT FOR A SIXTEEN-INCH HIGH PRESSURE STEAM MAIN.

BY R. E. CURTIS, BOSTON, MASS.
(Member of the Society.)

1. All engineers will probably agree that slip or swivelling joints in steam lines are commonly undesirable. Nevertheless, there are frequently cases in which some form of such joint cannot be avoided, and it becomes of importance to reduce its inherent disadvantages to a minimum. The swivelling joint here described was designed to meet a special situation, but its size and construction are such as, perhaps, to make it of some general interest. The problem presented was that of making a full-sized connection between the ends of two 16-inch mains, carrying 160 pounds pressure, lying parallel to each other and of such length that the relative movement of the ends by reason of expansion amounted at times to several inches.

2. The first form of connection to suggest itself, and in all respects the most desirable, had it been practicable, was by a simple loop of pipe. A little calculation, however, showed that this could not be used without danger of excessive stresses being set up. Then, several forms of flexible connection were investigated, and the final design adopted as being on the whole most satisfactory in the following particulars: (a) reasonable form and dimensions, (b) form and arrangement of parts under stress, (c) least number of joints requiring packing and removal of those from points where water might collect. All details were designed for a working pressure of 225 pounds.

3. Each joint consists of two elbows held together by a system of links—a flange bolted to the upper elbow and a length of pipe projecting downward from the flange into a stuffing box formed in the lower elbow, as in Fig. 177. Two of these joints are used,

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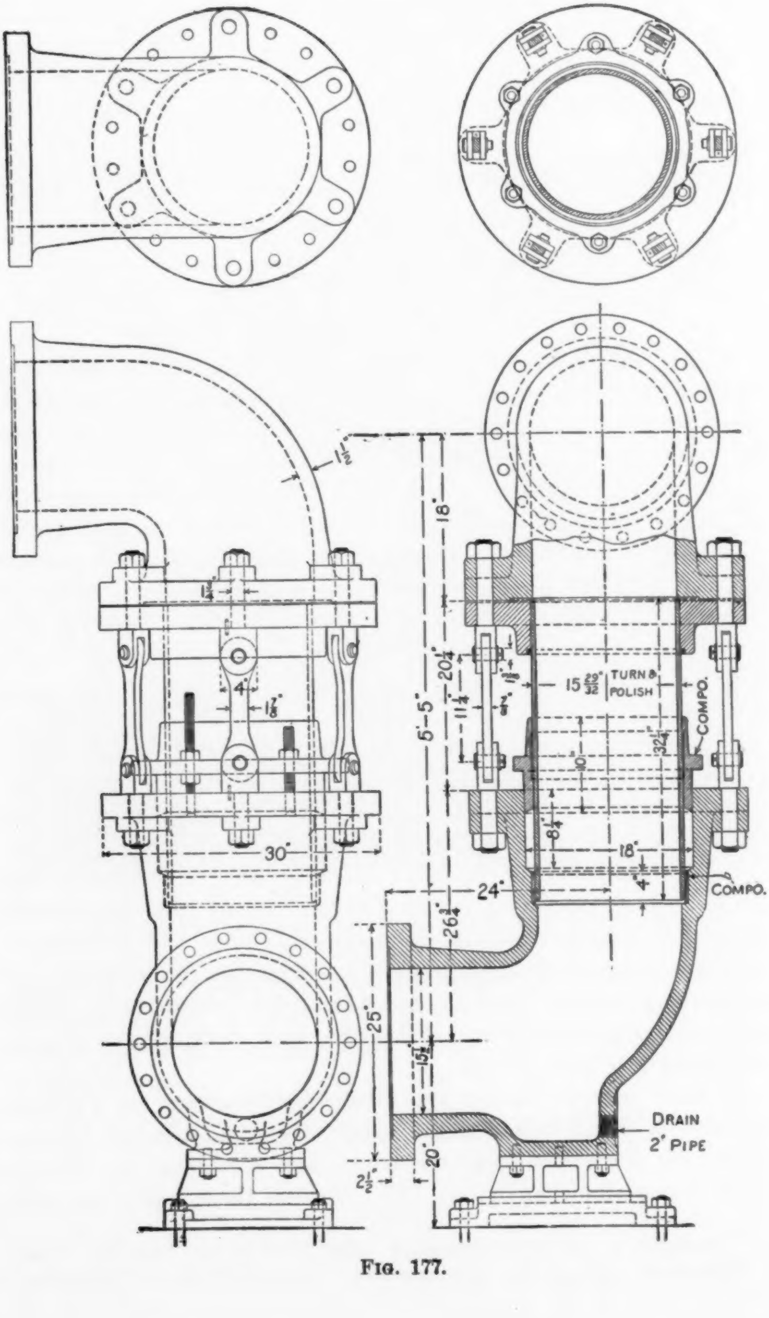
* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.



1½
18"
1¼
20¼"
5'-5"
4"
1⅞"
11¼
15 29/32" TURN & POLISH
COMPO.
32¼"
10
8¼
18"
30"
24"
4"
COMPO.
26¼"
25"
15¼
DRAIN 2" PIPE
20"
2½"

FIG. 177.

the lower elbows being secured to the ends of the mains and the upper elbows joined by a length of pipe. The elbows and flanges are of air-furnace gun-iron and are of substantial dimensions. The pipe is a piece of 16-inch O. D. pipe, $15\frac{1}{8}$ inches inside diameter, finished smooth on the outside. The gland and the ring at the bottom of the stuffing box are of composition, the former being held in place by six studs, three of which are long enough to hold it in a position to allow the packing to be easily gotten at. The ring and each end of the gland are made easy fits about the pipe. The endwise pressure is taken up, and at the same time the rotation of the joint provided for by six mild-steel links carefully fitted and so proportioned that the entire load can be borne by three with ample margin for safety. These links with their supporting bolts form a simple system, which insures a fairly even distribution of stresses and is always open to observation.

4. Each complete joint is carried by a sliding support consisting of a chair cast separately (to avoid complication of the pressure part) and bolted to the lower elbow and a bearing plate anchored to the masonry floor. The stuffing box was made of generous depth, and so proportioned that metallic packing could be employed if desired, but so far only asbestos packing has been used, and the joint has ordinarily been perfectly tight.

5. Conditions unforeseen at the time of making this installation have led to a radical rearrangement of the entire system of steam mains, so that a connection of this kind will no longer be needed, and the swivels will go out of service during the present year. However, had this not been done, there is every reason to believe that they would have continued to serve satisfactorily as long as any other part of the mains. Certainly they have in almost three years of service proven so satisfactory and required so little attention that there would be no hesitation about duplicating the construction under similar conditions.

DISCUSSION.

Mr. John D. Riggs.—It may be said that expansion joints are a thing to be avoided where possible, but it may not always be possible to avoid the use of them.

Four years ago, in connecting four large engines to their boilers, a swivel joint was used, which is somewhat cheaper than the one illustrated in this paper. The openings of these engines were one

18-inch diameter and three 16-inch diameter, upward, about 15 feet from the wall of the mill, 12 feet above the floor, and from 60 to 70 feet apart. From the boilers to the nearest engine is some 200 feet.

I solved this problem by running two lines of pipe—one 20-inch diameter and the other 18-inch diameter—along the wall of the mill and putting **T**s opposite the first and third, and elbows opposite second and fourth engines opening upward and on a level with the engine openings. A length of pipe about 11 feet long with an elbow on each end completed the connection. These elbows are standard fittings with tongue and groove for packing, but the bolts used here were $\frac{1}{4}$ inch larger in diameter, and the bolt holes at the head end of bolts were elongated to allow the elbows to swivel on their horizontal faces.

This form of swivel joint was not used on account of its cheapness, but because a travelling crane prevented the use of a joint similar to the one used by Mr. Curtis.

These joints, eight in all, have been working satisfactorily under 120 pounds steam.

*Mr. Curtis.**—I have noted, with interest, Mr. Riggs's description of his expansion device, and what he says of its performance would seem to indicate that it was a satisfactory design for that situation.

I have, however, grave doubts whether such a construction would be satisfactory under the higher pressures common in central station service. It is my conviction that when flanges have been bolted up as firmly as is necessary to maintain the tightness of joints under such conditions, that slipping of the contact surfaces will not take place, and that, in such cases, the piping should be so proportioned that the expansion can be entirely taken up by springing the pipes within the limits of safe working stresses; and where, for any reason, this cannot be done, some form of connection of assured flexibility should be used.

Of course it is to be understood that the device shown in the paper is not capable of unlimited application, but has been very successful under the conditions for which it was designed.

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* Author's closure, under the Rules.

No. 935.*

STEEL AND CONCRETE COAL STORAGE PLANT.

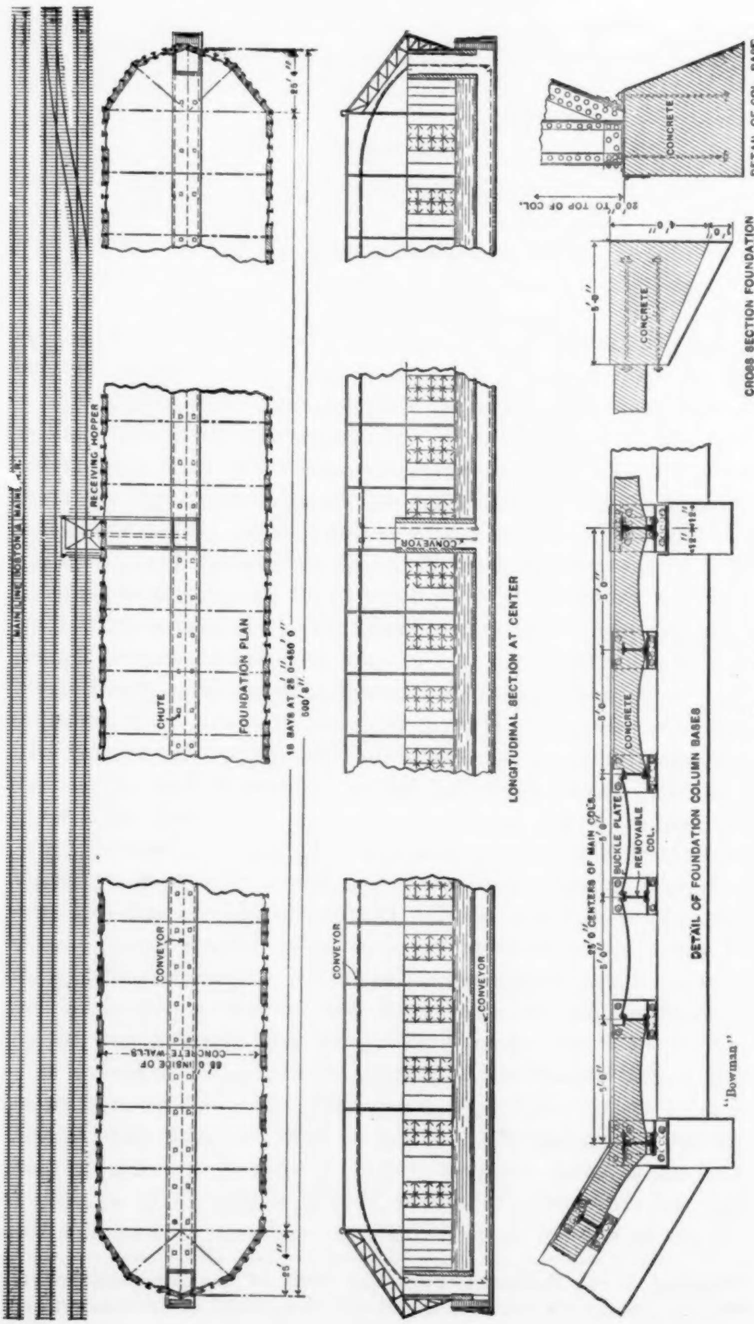
BY FRANKLIN M. BOWMAN, PITTSBURGH, PA.
(Member of the Society.)

1. It is the intention in this paper to describe the Coal Storage Plant of the Lowell Gas Light Company, Lowell, Mass., but we shall also touch on the general construction of such plants.

Previous to the building of the new storage plant, old shallow wooden sheds were used, some of which were very antiquated; no modern system of conveying machinery of any kind was used, and the cost of handling coal was quite high. When it became evident to the management of the Gas Company that large improvements would have to be made in all parts of their plant in order to reduce the cost of manufacture and to increase the output, they were at first inclined to allow the storage buildings to remain as they were, except that coal handling machinery over the old storage was proposed. Having in mind, however, their probable future requirements and considering the limited space they had for remodelling and extending the other parts of their plant, they finally decided to put up a large, modern and substantial storage plant, to hold 25,000 tons, about twice the previous capacity.

2. It will be noted by Figs. 178 and 181 that the coal storage building runs parallel to the Boston & Maine Railroad, the track immediately adjoining the shed being on the Gas Company's property. This arrangement allows ten cars to be placed on this siding at one time, and with the unloading hopper in the middle of the length of the building one-half of these cars can be loaded, so that unloading and moving of cars can be carried on continuously, without shifting engine. There would have been some advantage in running the building at right angles to the position decided on, as, with one end of the building against the railroad siding, the coal conveyor would have a straight run, so that it would not be subject to the extra wear and tear, and require the

* Presented at the Boston meeting (May 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.



MAIN LINE BOSTON & MAINE R.R.
RECEIVING HOPPER
CHUTE
FOUNDATION PLAN
CONVEYOR
68' 0" INSIDE OF CONCRETE WALLS
18 BAYS AT 25' 0"=450' 0"
500' 8"
25' 4"
LONGITUDINAL SECTION AT CENTER
CONVEYOR
CONCRETE
DETAIL OF COL. BASE
20' 0" TO TOP OF COL.
CROSS SECTION FOUNDATION
5' 0"
DETAIL OF FOUNDATION COLUMN BASES
25' 0" CENTERS OF MAIN COLS.
BUCKLE PLATE
REMOVABLE COL.
"Bowman"

FIG. 178.

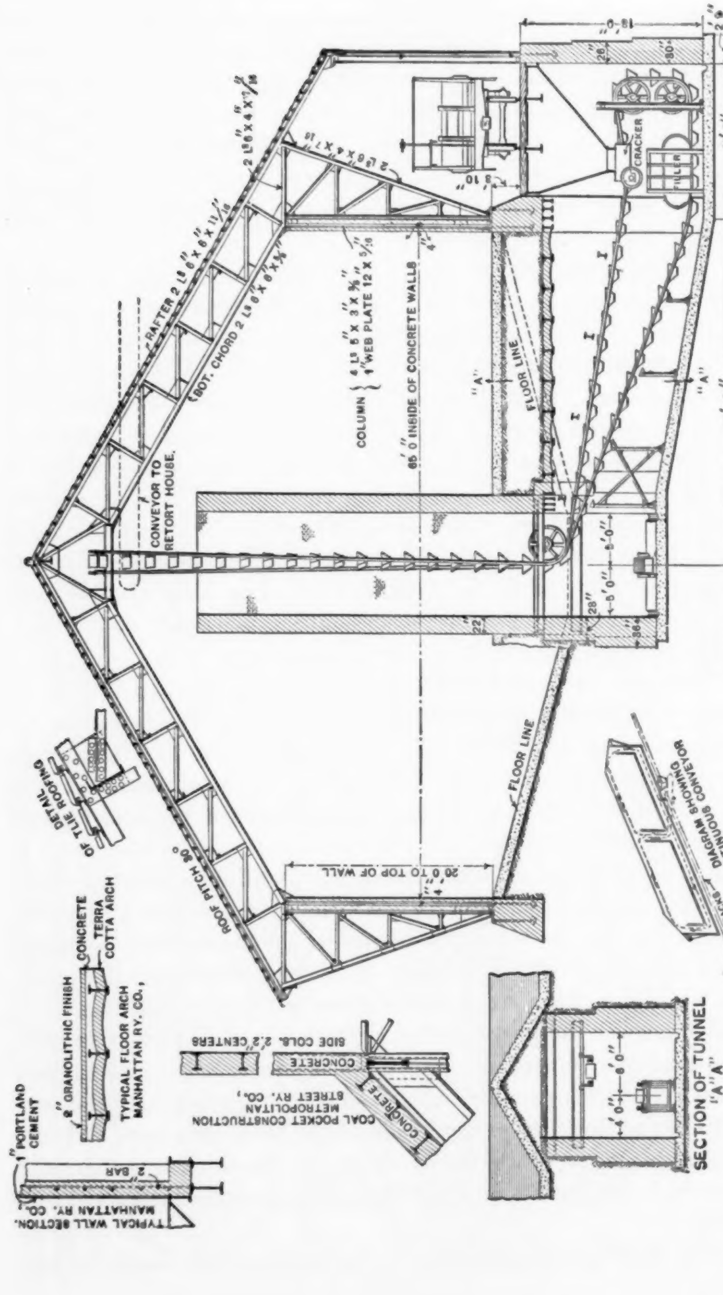
constant extra power necessary to pass round the turns of the tunnel leading under the unloading hopper. Also under this construction the concrete shaft in the centre of the building would not be required. It was necessary, however, to locate the building in the position decided on because they could not disturb the present coal sheds and retort house, as it was necessary to run them continuously while the new buildings were being constructed, and, further, the general scheme required the space of the old coal sheds for other improvements.

3. In the design of the plant, every effort was made to obtain not only a useful and permanent but handsome structure, if a coal storage can be called handsome. It is a steel frame structure with concrete walls, foundations, and floor and with a tile roof resting on steel purlins. It is fireproof throughout, well ventilated and lighted, protected as much as possible from corrosive influences and arranged so that the pocket can be expeditiously emptied should there be fire from spontaneous combustion, or other causes. The steel truss is braced from the outside of the building, the main columns being vertical; with this construction, these columns, with the concrete wall, form the bulkheads for the coal; the inclined back leg, forming the brace at each column, is outside of the storage and supports the overhang (see Fig. 179).

4. A further reason for the use of this construction is that an inclined floor, with a tunnel in the centre of the building, was required, and these conditions made it impossible to put in tie rods across the building to unite the bases of the main columns, and thus take more of the wind strains and the pressure of the coal against the sides of the building.

The shallow truss with bottom chord parallel to the top chord makes it impossible for the coal to reach the truss at any point, while the channel tie across the centre of the truss, near the ridge, forms a support for the conveyor. It may be noted that the building is without a ridge strut, but the two girders on either side of the ridge answer the purpose, and at the same time form a support for the conveyor, as well as a guard for the foot walk. The shallow inclined truss, with the tile and glazed roof, together with the concrete walls and floor, gives the inside of the building a neat and substantial appearance, while the overhang on the sides, together with the tile roof, and the octagonal ends makes the exterior appearance pleasing.

5. The floor and foundations of the structure are made of con-



TRANSVERSE SECTION
FIG. 179.

crete, the foundations having an inclined back wall slanting away from the building. The building is so designed that the main columns have no horizontal thrust at the base, but the small intermediate columns have the thrust of the coal at their base, thus taking care of the pressure of the coal against the sides of the building.

The roof is covered with Ludovici tile, the finish of the tile being what is known as non-glazed or semi-porous. Except for its expense, glazed tile would be satisfactory for this structure, because any sweating and dripping inside of the building would do no harm. Unglazed and semi-porous tile, well burnt, is necessary in such buildings as a power house or machine shop, so that there may be none of this dripping. The tile does not, as might be expected, freeze and crack in cold weather from the absorption of water. During a cold spell last winter, lasting almost two weeks, the shed became covered with ice and snow, mostly ice, to an average depth of four inches, but the tile has, apparently, not been injured.

6. Light is obtained principally through skylights in the roof, made of glass tile of the same form and size as the ordinary tile and laid on the roof in the same manner. Additional light and ample ventilation is obtained from the opening between the roof and the top of the wall.

It is to be noted that the coal in this building is stored on the ground and not in an elevated structure; wherever possible, it would seem that coal should thus be stored, and where this is impractical it is important that the inside of the storage be entirely lined with concrete, so that no part of the supporting steel work is exposed to the corroding action of the coal.

Public attention has recently been called by Mr. Sooysmith to the possible danger due to corrosions in tall steel frame office buildings, but danger from this source is largely accentuated in a coal storage, with its sulphur and other corrosive substances. For this reason, where a permanent and costly structure is to be built, as is usual in the case of large power houses, coal bins lined with steel plates should not be used, as they are liable in time to become a menace to life and property.

7. In the case of Lowell, all main columns, and as far as possible the intermediate columns, are entirely covered with concrete. The steel work which is exposed cannot be reached by the coal, can readily be painted and is made throughout of heavy material.

The coal storage pockets of the power houses of both the Man-

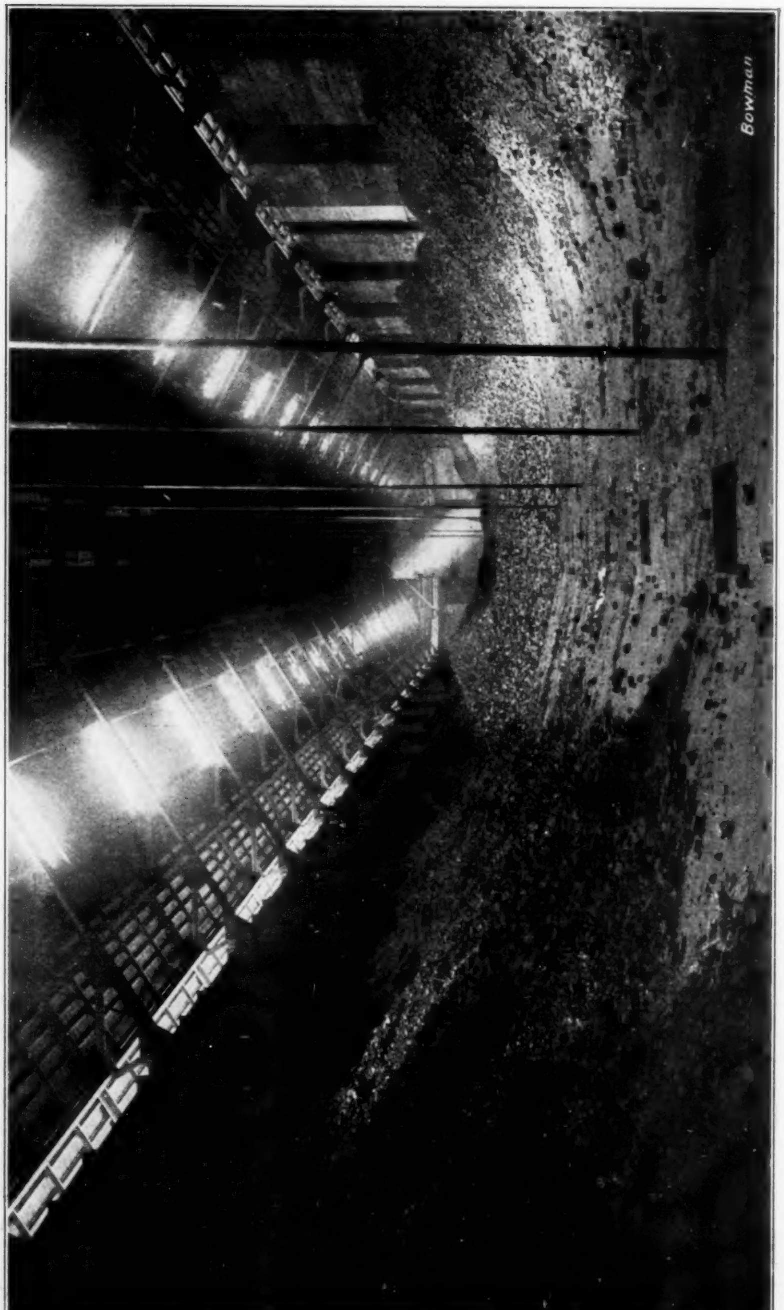


Fig. 180.

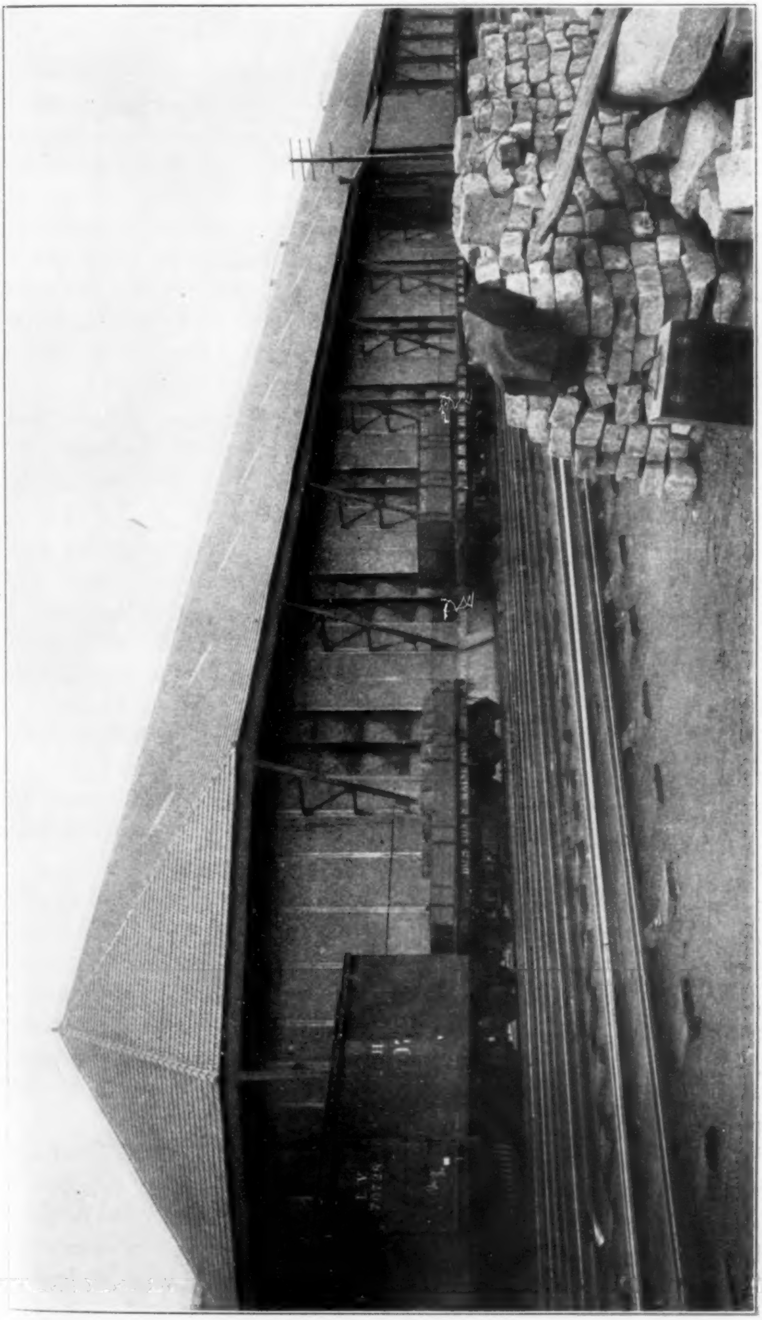


Fig. 181.

hattan Railway Company and the Metropolitan Street Railway Company, of New York, are steel structures, and are constructed along the lines indicated (Fig. 179), the steel framework being covered with concrete. The Manhattan Railway Company adopted the Columbian system, which consists of putting in small special beams about 2 feet apart, thus allowing the main beams to be spaced further apart than otherwise. They are thus able to use a less thickness of concrete and effect a saving in weight, cost and space. Another similar and very good construction in use is either expanded metal or wire netting covered with concrete. The essential point is to have the steel framework, and especially the joints, entirely surrounded and imbedded in concrete, as under these circumstances steel will not corrode.

8. On account of the limited space on the property for the coal storage plant, it was necessary to keep the building narrow, and consequently coal had to be piled to the considerable depth of 40 feet. It was therefore thought best to design the pocket so that it could be promptly emptied in case of fire from spontaneous combustion, or other causes. With this in view the floor was given a pitch of fifteen degrees towards the tunnel in the centre of the building, so that the two sides can be easily and well drained of coal by the conveyor; that it is so is shown by the photograph of the interior (Fig. 180), which was taken after the shed had been filled and emptied. In order, however, to expedite the removal of coal in case of fire, two panels in the sides out of every five were made of removable steel buckle plates with a movable column in the centre; these can be unbolted and moved promptly and coal can be taken out of this opening; it is 10 feet wide.

In connection with this matter of spontaneous combustion, the upright wrought iron pipes seen in the photograph of the interior (Fig. 180) are to be noted. These were installed by the superintendent, Mr. T. H. Hintze, with a view to determining, approximately, the temperature of the coal by means of a thermometer held at the upper end of the pipe. In this manner any coal in the storage which shows signs of becoming heated can be conveyed to the retort house and used.

9. Reverting to the machinery, the conveyor (Fig. 182), is of the gravity bucket type, in which the buckets are 18 inches wide by 24 inches long, pivoted in the chain in such a manner that while they maintain themselves normally in an upright position, they can turn through a complete revolution. The chain is composed of double

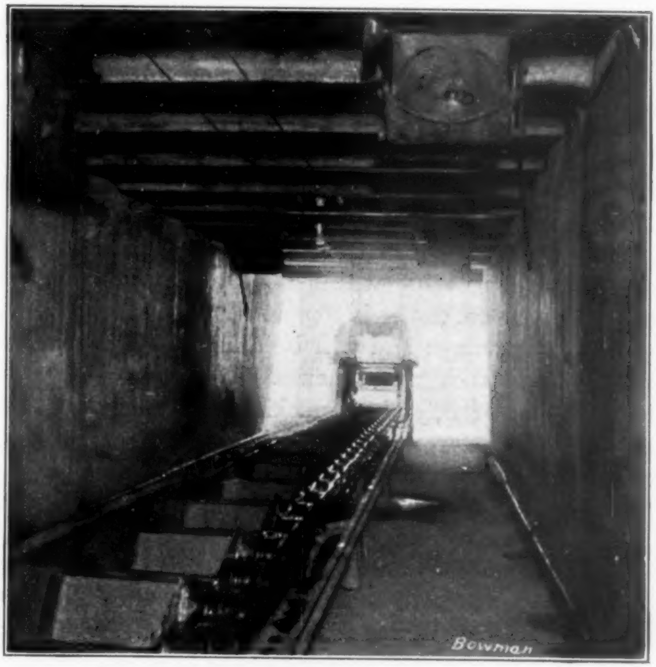


FIG. 182.

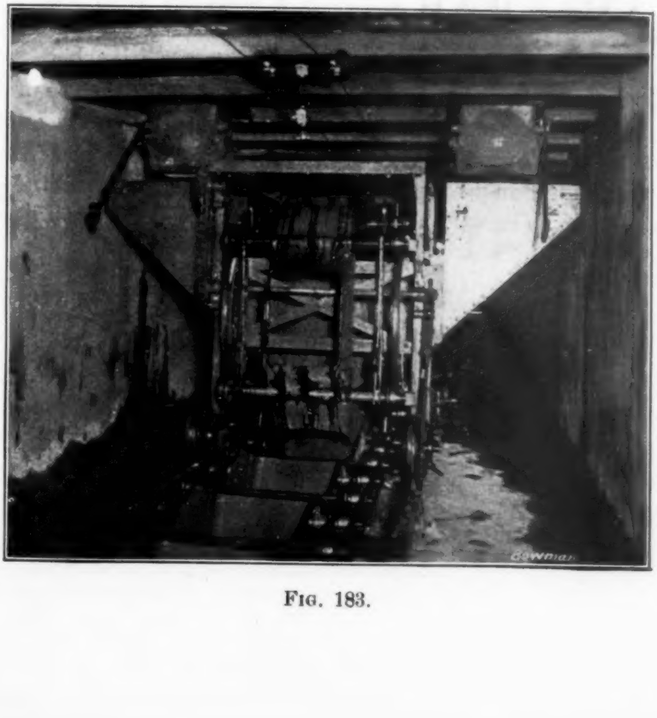


FIG. 183.

flat links of steel, and the conveyor moves about 40 feet per minute.

The driving mechanism is located in the truss and is operated by two 6x8 steam engines of non-freezing type. This mechanism is peculiar, from the fact that instead of sprocket wheels the chain is driven by pawls, thus reducing the wear and imparting a smooth and uniform motion. The machinery receives the coal from the hopper under the railroad tracks, cracks the lumps to a uniform size and carries them without transfer to any part of the building. When the new retort house is completed, coal will be taken from any part of the storage and will be delivered to a separate conveyor leading to such retort house. It is to be observed that all the functions of receiving, cracking and rehandling, are performed by the conveyor, the receiving section of which can be detached when rehandling coal from storage. The coal is drawn into the conveyor by means of adjustable cast iron valves (Fig. 182), which have no sliding surfaces. When the valves are closed, the column of coal above does not tend to open them. Before the valve is open the filler (Fig. 183), which runs up and down the length of the tunnel, is placed in position under such valve; the coal then passes through the filler to the conveyor.

10. In general it is to be noted that the plant has been designed with a view to securing a durable, neat and suitable structure, and no reasonable expense was spared to obtain this result. The work was carried on most expeditiously, especially considering the difficulties in connection with the foundations, where sewers, pipe lines and rock blasting had to be contended with. Ground was broken in March of last year and the plant was completed in September, so that five months was the time required for its construction.

No. 936.*

LIQUID FUEL COMBUSTION.

BY CHARLES E. LUCKE, NEW YORK.
(Non-Member.)
PRESENTED BY R. H. FERNALD, NEW YORK.
(Associate Member of the Society.)

1. OIL combustion, considered as a rather complicated series of physical actions, has never received the attention due to its importance. There have appeared from time to time men who, taking up the corresponding question for gases, gave to the world a series of researches which leave but little to be desired, and the very perfection and elasticity of our methods of burning gases brings into stronger relief the narrow limits of present practice in oil combustion. Before we can hope to design special and proper furnaces the problem must be attacked from this standpoint, and the physical operations will, when brought together and classified, give us the principles of oil combustion. A detailed and minute treatment of this question would call for a lifetime of study, but some of the principles are more prominent and appear more evident than the others; a few of these have appeared in the course of some experiments undertaken for an object noted later.

2. The analytical treatment of the combustion of gases greatly simplifies the problem of oil combustion. By classifying the gas-burning methods according to the mode of bringing the air and gas together, it was found that there were, broadly, two great divisions of all systems, those in which a supporting atmosphere was necessary, and those in which, because of the self-propagation or explosive property of the burning mass, no supporting atmosphere was necessary. Moreover a distinctly different set of laws of physical action holds in each case. The laws of combustion for

* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

explosive mixtures with their volumeless flames are radically different from those for all other mixtures the combustion of which calls for a supporting atmosphere, giving rise to a volume of flame due to the meeting of the fuel and oxygen at different points, and at each springing into flame when juncture is effected. The volumeless flame of the true explosive fire depends for its localization and maintenance on the relation between the rate of propagation of inflammation in the mixtures and the velocity of translation, together with the extent of freedom from diffusion of the fresh mixture with the products while approaching the combustion surface.

3. For a comprehension of the different cases of oil burning, we must add to our knowledge of gas combustion something on the vaporization of the oils, since it is conceded that oil will not burn as such, a distillation or vaporization preceding the actual combination with oxygen. So that different oil systems will differ chiefly in the method of producing the oil vapor, and in the method of causing a meeting of this vapor with the air. Any two systems which agree in these two points must be brought together as coming under one class, but perhaps differing in details which may or may not be essential to good results.

4. Of all the different systems proposed we can, according to the above, note only three different general classes:

I. The burning of oil in an atmosphere without previous treatment by air or heat. This class burns the oil (*a*) from a surface either that of the liquid mass or that of films artificially produced by sand, stones, fibrous or metal wicks. The vapor burns immediately as formed, and hence there can be no mixing with air, the flame existing merely in an atmosphere which may be often renewed or not, depending on blowers or merely convection. The fires resulting from this class are grouped for action and effects with the first kind of gas combustion, a jet of gas issuing unmixed into an atmosphere of air.

There may also be included (*b*) those retort, or (*c*) spray vapor producers which deliver oil gas, as just noted.

Oil burning by methods coming under this class must be subject to the same merits and defects as the gas combustion noted, however diverse, complicated, or ingenious the details of operation or construction may be.

II. Under this class will be grouped all oil fires capable of producing what is known in gas combustion as the "Bunsen

effects." That is to say, the oil is vaporized in such a way as to permit the mixture with it of a certain amount of air before it reaches the existing flame, and having reached the existing flame requires an oxygen atmosphere to support combustion.

Any system producing vapor which can be handled as can a gas may also be included.

III. The third class of oil combustion will include all those methods in which the oil is vaporized and mixed with air in such proportions and in such manner that there will result an explosive mixture of oil vapor and air. Such oil fires will be subject to the laws of combustion of explosive mixtures. The vapor may be produced in retorts by boiling a mass of liquid, or by spraying oil on hot surfaces and then conducting it to a point where it may mix with air, or the oil may vaporize by contact with or approach to a hot surface in the presence of the air.

5. The most natural and earliest practical method of oil burning was that of simply lighting the surface of a mass resting in a pan. The amount of heat that could be developed depending on the surface of oil exposed led to a spreading of the oil over plates and running over numerous grooves and in the formation of cascades, etc. The high flash point of some oils, *i.e.*, the high temperature at which they give off combustible vapor and the presence of the liquid mass made it impossible to burn them in this way, and hence was brought about one of the first improvements in oil combustion. The wick system results from a desire to produce more vapor, and this from oils of high flash point; by it oil is caused to spread out over a large surface in as thin a film as possible, and is then subjected to heat. Being in a thin film it is easily vaporized because of the small quantity at any point and the ease with which the substance supporting the film can be heated and kept hot, the vapor thus produced burns as it appears in an air atmosphere.

When the film bearer has a low specific head the vaporization is the more rapid at the surface but slower beyond; with a metal film bearer the conduction of heat beyond the surface causes a vaporization at more points and insures more complete vaporization by a superheating at the surface; the superheating may even decompose the vapor.

6. These wick burners are easily illustrated by a pile of sand, fragments of brick or fibrous material in a pan of oil; wire net may also be substituted for the fibrous or other material.

For these burners to work at all the surface, at least, must be hot, and when acting in an atmosphere the latent heat of evaporation of the oil will tend to keep the temperature down, resulting in steady conditions. There will always be a limit of rapidity in

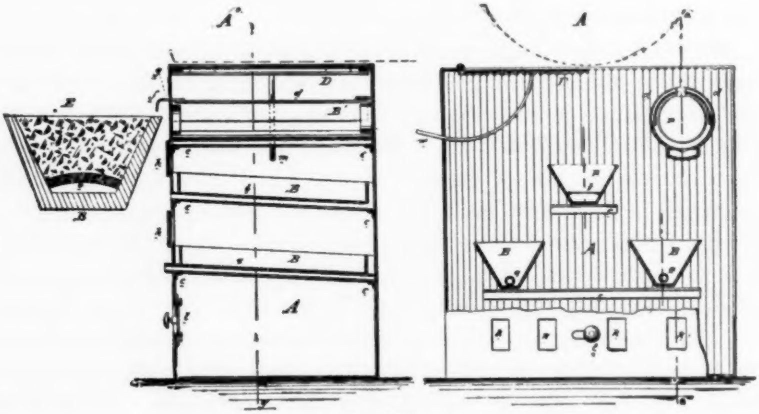


FIG. 184.

such combustion, since a constant state will be reached for the wick temperature and rate of evaporation, and, consequently, for the combustion, making regulation difficult.

7. Such systems must necessarily be slow heat producers, how-

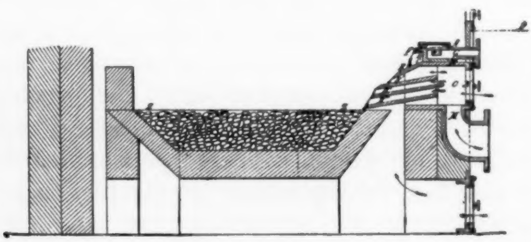


FIG. 185.

ever perfect the combustion, and to disadvantages of the first class of gas combustion, we must add a few more characteristic of the methods of evaporation.

Fig. 184 shows the simple pan-wick system of Weeks, and Fig. 185 the cascade of Verstract, which is combined with a wick at the bottom to burn what escapes from the cascade. This is selected for illustration because it is also an example of an attempt to pro-

duce Bunsen effects in the mixing of air with the vapor. It does not succeed in this, however, because when the liquid surface is present the flame will locate there, and the air blown through the slits *R* on the falling oil sheet can only have the effect of an often renewed atmosphere, *i.e.*, a wind; no mixing of vapor and air is possible.

8. However, the surface of vaporization is increased, hence more vapor is produced, and, in addition, the air blown through helps to accelerate the combustion; but in spite of this the action is precisely the same as before, a flame of oil vapor burning in an

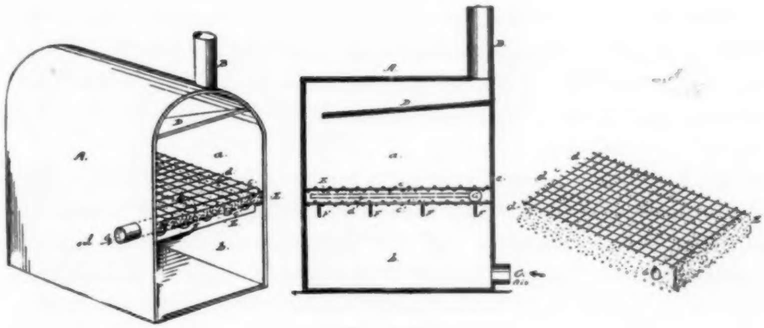


FIG. 186.

atmosphere of air. The improvement then is not one of class but of detail.

Improvements of the same sort on the wick method, aiming to lift the wick from Class I. to Class II., and get Bunsen effects result in the same way. Air blown through the wick chills it and retards vaporization, in addition to slightly lifting the hot part of the surface-flame farther from the vaporization surface, which should be kept hot. An illustration of this, Fig. 186, is the method of Hubbard. A mat is provided with a pipe system to deliver oil at numerous outlets in the mass, with the intention of saturating the mass. Then air is blown through the mat. The intention is to vaporize the oil in the mat by the heat from above, and the vapor, mixing with the air passing through, is to ignite on the top. It will be readily seen that as each outlet is a source of oil feed to the mat, we have a large number of wicks grouped with air blowing on them.

9. Supposing a vaporization to take place immediately on issuing, as is expected, and which fact, of course, depends largely

on the fuel used, we will have each nozzle a source of gas, and there will result a number of gas jets blowing into the mat. The ascending air current will lift the gas jet, and there will result practically a cone of gas with apex at the orifice, surrounded by air. At the edges there would be some diffusion, and beyond the cone a moving atmosphere of air. If the mat were thick enough and the air current not too swift, there might result an approach to a Bunsen flame in an atmosphere of air within the mat. If the mat were not thick enough, and the air current moved too fast, there would be at the surface a Bunsen effect. In no case could there be an explosive effect of Class III., because of the relation of air and oil vapor supply, the one surrounding the other, making at every point a constantly changing proportion. Were the air and oil vapor discharged into the mat through the same orifice the effect would be quite different, as will be seen later.

10. Air blown on the top of a wick makes the flame a little more vigorous only because it renews the atmosphere instead of depending on convection, but the process would not change the combustion otherwise. The two systems of surface evaporation from the liquid mass and from the wick film both demand, in order that the action may be continuous and non-clogging, an easily vaporizable oil which will not distil into parts of different vaporization temperatures. With such an oil obtainable, of course the next obvious step is to simply boil it in a retort, producing vapor which can be used exactly as is gas and by all the means known for gases. However, an additional precaution must be taken, that of preventing decomposition of the vapor produced by undue heating before burning.

This would be a great advance over the methods noted before; given only the proper fuel, and we can produce any sort of fire from the illuminating flame, through Bunsen and blow-pipe effects to the more recent explosive fires with their high temperature and rate of consumption, and with each obtain perfect regulation.

11. To vaporize oil in retorts requires that;

(*a*) The oil be not subject to fractional distillation, but that all of it must vaporize at the same temperature for any given pressure.

(*b*) The temperature shall not rise above this vaporization temperature, or decomposition of vapor will result with deposit of carbon to choke the passages.

(*c*) The vapor once produced must be prevented not only from superheating before reaching the fire, but also from condensing.

These conditions are exceedingly difficult to get, and no oil cheap enough to be used for fuel in competition with coal is available for the system which is otherwise very attractive in its simplicity and range of possible effects.

12. These oil vapor producers may be operated by (*a*) the boiling of a mass of oil, (*b*) the vaporization of a spray, stream, or drops by contact with hot parts, and (*c*) by the carbureted air method. The first two, so far as their resultant effects go may be grouped together, but the third has been found of value in many cases where the selection of the required fuel is not prohibited. Air is brought in contact with liquid surfaces, and passing off carries some vapor with it. We have here a mixture of air and vapor burnt in the atmosphere of air, or we may go farther and form the explosive gas requiring no atmosphere to burn. In just what proportions of air and vapor the mixture will be delivered from the carburettor depends on the temperature of the air, the intimacy and length of time of contact with the liquid, and the temperature at the evaporation surface. Of course, the temperatures of the carburettor will tend through evaporation to become continually lower, and this must be guarded against.

13. These oil vapor systems differ but little from the pure gas systems, and whatever can be done with gas can be done with these vapors, giving fires of classes I., II., and III., provided the proper fuel is available, and, if the necessity for the fire is so urgent that cost is not the most important consideration, they may be very useful.

We have not yet noted, however, any system which will enable us to burn heavy oils, or those which fractionally distil leaving a residue, and of these petroleums and some of the petroleum products form the largest and cheapest source of liquid fuel supply.

With the spray or atomizing system we have something radically different from these so far considered, inasmuch as any kind of oil may be used and a good fire obtained with each. Here the oil passes through a small opening, where it meets air issuing at a high velocity and is by it thrown into the firebox as spray. The firebox being filled with flame and lined with brick also quite hot, each particle of oil is vaporized in the presence of air, and the products of combustion of previously consumed oil particles.

14. The temperature of the fire resulting is extremely high, and this led to the use of steam for the spraying agent, the injecting nozzle having other openings through which air passes under the influence of the chimney draught and partial vacuum produced by the jet.

The action here is probably more nearly explosive than anything else. It was noted that the rate of propagation of combustion in explosive mixtures is very much increased by high temperatures. When an explosive mixture is forced into an enlarged chamber previously made very hot, blow-off is prevented for quite a range by this increase in the rate of propagation. The oils commonly used in the spray have a very high temperature of vaporization, and it is more than probable that, moving with the air in the hot parts of the firebox, at the high temperature of the mixture when vaporization takes place, the rate of propagation becomes so high that blow-off does not occur. However the action is not the best even though explosive, for there is a large admixture of products with the jet, particularly at the edge and at reflecting surfaces.

15. The entering jet, approximately conical in form, is composed of a large number of oil particles, each surrounded by some air and some steam. As the jet approaches the hot section, the oil springs into gas and the gas with the air into flame, the steam is inactive until very high temperatures are reached, when it decomposes and acts as a cooler. The vaporization of the oil is accomplished either in space while the oil particle is in motion surrounded by air, or by contact with some of the solid surfaces of which a good many are provided in the form of arches, bridges, baffles, etc. All that can be seen is an orange glow and the course of the jet is invisible, except near the nozzle.

The system requires that the spray be formed, and for this air or steam under sufficient pressure must be provided, numbers of baffles and bridges to break the current after it has entered, in order to scatter the jet and distribute the heat; a firebox of sufficient capacity to allow the formation and vaporization of spray and its final combustion; small openings at the nozzle.

16. Many auxiliaries to the spray have been used, but of these the most notable is that of Kermode, who sprays with heated air directed upon a bed of bricks or asbestos placed on the fire area. He provided this loose fire-bar covering simply to cover the bars

easily but noted that by their presence the action was improved, for a reason which will be seen later.

While most of these spray systems depend on a pressure drop of air or steam to atomize the oil and these seem to have given the best satisfaction, yet there are some others which work on the few ounces pressure of a fan. The oil is conducted to sharp points by capillary action and blown from them by the blast; tests of these generally show higher oil consumption than the compressed-air system, probably because of the lower temperature, resulting from more air and slower burning.

17. The subject of oil combustion in general is very interesting to the laboratory experimenter, and as a system was desired which would burn enclosed under pressure for use in the internal combustion-engine, a series of experiments was undertaken at Columbia University to find, if possible, a method which was adapted to these conditions.

With the knowledge of what had been done with oil fires in other applications as a guide, the first series had for its object the determination of the principles which should govern enclosed pressure fire systems. These principles once determined, it was hoped that the desired method would appear. Some of the experiments made together with the deductions therefrom are here briefly presented for a record, as they may be of value to other workers in the field. Engines which work by passing air through a fire and thus expanding the volume at constant pressure, impose on the fire some conditions not easy to satisfy.

18. Air must be compressed into the firebox, and at each delivery of the compressor there will be a pressure increase on the fire; similarly at each admission to the engine cylinder there will be a pressure drop, and while we may call the system a constant pressure combustion system, this cannot be strictly true. What is constant is the mean pressure, and even this may vary after a limited time, for variation of admission and cut-off will change it. So that a fire to work successfully in this apparatus must be unaffected by pressure variation whatever may be its extent or suddenness.

One of the greatest advantages which may be derived from this type of engine over the explosive, for example, is the possibility of employing the cheap and safe heavy oils. But to realize this advantage we must add to our conditions one imposing the requirement that heavy oils shall be burnt. And finally, the products of

combustion must be delivered at a constant temperature, and that as high as possible. Moreover, this maximum must be known to the designer who proportions his cylinders and mechanism for some particular volume expansion dependant on this maximum.

19. The most radical difference between these conditions and those imposed on an ordinary fire is that of burning, enclosed under a pressure which may vary widely and suddenly; so it was decided to first try to obtain a fire which would do this regardless of the fuel used or the delivery temperature, and this being attained to experiment with the other conditions by making appropriate modifications.

20. One burner which seemed to give a good steady Bunsen effect in ordinary use was that of the gasolene or kerosene

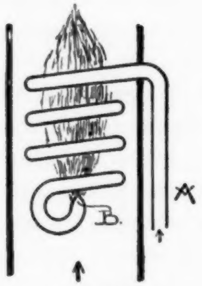


FIG. 187.

soldering, torch, or cook stove. This seemed so simple and unlikely to be affected by pressures that the principle envolved was that first tried, oil fed through a self-vaporizing apparatus and escaping as gas.

Kerosene was fed through a coil of small brass tubing as shown in Fig. 187, the oil flowing from the top toward the bottom burning at *B* and playing on the coil. It was expected by a long coil to obtain a perfect vaporization. This device was found exceedingly irregular in action, no matter how carefully the feed was adjusted, the vapor delivery was never steady, varying from a long flame to total extinction. Matters were somewhat improved by enclosing the coil in a shell insuring a uniform heating throughout. After working for some time in this way the operation stopped, and the tube was found full of solid carbon at the lower part, showing a decomposition of vapor in that part. Gasolene, alcohol, etc., could be used, but not petroleum and heavy oils.

21. There were two faults prominent in this arrangement: first, the down-feed through a variously heated coil, gave rise to uneven vapor generation; second, the passage of the formed vapor through the heated part where decomposition could occur.

In the next burner it was intended to do away with both of these faults, the first to be eliminated by having a large mass of liquid boiling, and delivering vapor in such a way as to avoid superheating and so eliminate the second fault.

The apparatus of Fig. 188 was made. Oil enters at *A*, is dropped to *X*, where it boils in the chamber, being heated from below; the vapor generated passes around *BC*, feeding the flame. *B* is a valve which permits shutting off vapor delivery, and by the increase of pressure also the feed which was under constant head.

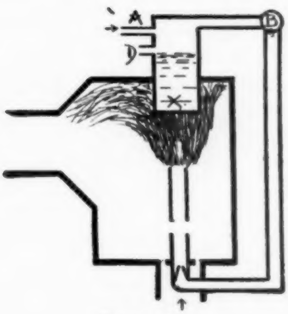


FIG. 188.

Any rise of oil level was prevented by the overflow *D*. Air entering at the bottom with the vapor a very good Bunsen effect could be produced when burning freely and with naphtha as fuel. When enclosed, however, and with pressure put upon the chamber the flame became very irregular, and any quick change of pressure always resulted in extinction. With kerosene there was considerable vapor condensation in the drip. Various modifications of these vapor generating pressure oil burners were tried, but all were unsatisfactory for enclosed pressure use. The boiling oil generates within its chamber varying pressure depending on the rate of boiling, and rate of efflux of the vapor. The rate of boiling or vapor generation, if the flame below is kept constant, will depend on the pressure on the surface of the liquid.

22. This, in turn, depends upon the pressure on the flame and the size of opening in the vapor pipe. We thus have a number of conditions surrounding the vapor supply, from which the air

supply is free, but the air supply has varying conditions of its own, and as these double conditions are never, as it were, in phase, the result is failure. The only way in which we can keep the proportions of air and vapor right is by observing the flame, and this is, of course, out of the question when it is enclosed. When conditions can be kept right, a very good fire can be made with this burner, using kerosene, gasolene, naphtha, alcohol, etc.

Some other experiments leading from this brought out the fact that much better results could be obtained if the boiling is confined to the surface of the liquid rather than allowed to exist throughout the whole mass. To get this result a pipe was bent, as shown, Fig. 189, and oil fed from below to the enclosed length, which becomes hot on top from the oil vapor jet *B*. With a constant head, a flame could be kept lighted under pressure, and enclosed up to the feed-head. A sudden change, however, created

FIG. 189.

trouble. The vapor delivery depends on the difference in pressure between the chamber and the feed-head, and the flame grows smaller, allowing the hot plate to cool when it should be getting hotter. The proportions could not be maintained at all constant under variable pressure, though the burner would work all right when proper adjustments could be made.

23. With a feed varying with the chamber pressure a slight improvement resulted, though even then the result was not satisfactory. There was carbonization at the orifice with kerosene, and the apparatus would not work at all with heavy oil. Sudden pressure changes invariably caused extinction. The amount which can be fed economically can be varied but little, and not so to keep any constancy of proportions with the air.

To maintain some such constancy of proportion was necessary, because the ultimate object of the oil fire was to heat the air, and different quantities of oil burnt in the same air will give different temperatures; and if the proportion cannot be predicted certainly

the final temperatures cannot, and the fire is useless for the purpose in hand. With the purpose of keeping some sort of ratio between fuel and air, an air suction oil lift was tried, Fig. 190.

24. It was not intended that the complicated action of the common atomizing spray should result, but only that the air should lift oil in quantity somewhat in proportion to its own quantity. This oil is blown with some air through a flattened attenuated opening *A*, where it is spread out without changing its velocity,

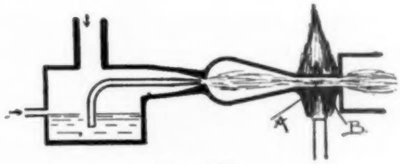


FIG. 190.

and then brought in contact with an externally heated plate, *B*, to be vaporized, the action being similar in effect to that of the carburettors used in Priestman oil engines. It was found that there was one rate of air feed at which just the right amount of oil would lift, a variation either way changing the action materially. When enclosed the slightest change of pressure results in bad action, sooting, flooding, and extinction. A number of similar injector oil lifts were made, and the conclusion reached was that none could be depended upon to produce the action desired. To further test the principle of carrying oil by the moving current

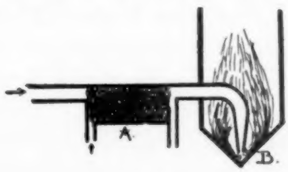


FIG. 191.

of air either as mist or vapor, the arrangement of Fig. 191 was tried. Here an irregular mass of wire net fills the chamber *A*, which is about one-half full of oil. The wire threads draw up by capillary action the oil from the surface, spreading all over the wires and some of the spaces between, making conditions very favorable for the air to take up either mist or vapor as the case may be. The issuing jet is reflected back upon itself and heats the nozzle, insuring that any mist shall become vapor.

25. The opening need not be small. It worked very well for kerosene and better for gasolene, and much better for both when heated air was supplied. This fact in addition to that of liquid collecting in the cone, *B*, seems to indicate that a mist rather than vapor was the result of the air passage over the net. This fact is further proved by the working under kerosene without dropping of temperature such as would occur with evaporation. With a steady set of conditions this apparatus worked well as was noted, but like the injector devices, no great variation of the fire could be made. It was tried with petroleum, and the result showed a collection of residues in *A*, only the lighter volatile parts coming off. A little carbonization appeared at the nozzle.

26. All these devices depending on the vaporization of oil at some point have given great trouble from regulation when en-

FIG. 192.

closed, and none was found satisfactory for variation of combustion pressure. It is probable that one could be designed, but it would necessarily be complicated. With the ones tried the temperature of the products could in no way be kept constant, and while most required large and variable excess of air, a few were found which could be operated by little, but the high temperature resulting invariably produced vapor decomposition. They required, moreover, special oils, but even this might be endured if a steady fire with always the same temperature delivery could be made to work under variable pressures; but these results could not be obtained.

27. The vaporization systems were now abandoned in view of these difficulties for the attractive simplicity of wick combinations which, while perhaps not offering the greatest perfection of combustion, yet would not go out when put under pressure. Fig. 192 was tried, with a bottom oil feed to the wick, and air supplied above. It was found that the wick at the bottom of the chamber was not affected by pressure, and burned steadily when enclosed, but a steady discharge was necessary, for when the discharge was interrupted the flame was extinguished. It seems as if the products must be conducted away at once, and this is probably because, with the wick, the vapor generation will go on some time

after the oxygen supply fails. It also seemed advisable to have the air current and flame tend towards the same opening and not oppose. Opposition produces a violent flame and irregular action which may cease entirely at any time.

28. To improve the means of renewing the atmosphere of this fire the burner of Fig. 193 was made. *A* is an asbestos mat supplied with oil from *B*. *C* is the air-supply pipe ending in the funnel *D*. If the oil be lighted at *A*, and time allowed for the whole to heat up, the burner can be enclosed and pressure applied

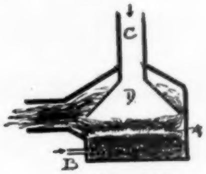


FIG. 193.

through the air-supply *C* without causing extinction. The pressure in the combustion-chamber has absolutely no effect on oil flame thus produced.

29. The products of combustion thus produced were piped to a small Shipman steam-engine to observe the effect of the impulse of engine admission on the action of the fire. Good results for any pressure were obtained with only one drawback. If the velocity of the air over the flame be too high, the flame will go out. With gas or oil previously vaporized a surplus as well as a deficiency of air will cause extinction; here, any surplus will have no effect, provided only that it move slowly enough. A most important result was here attained, viz., the flame could be kept going under working conditions.

For a more perfect and rapid combustion of oil by the wick method, it seemed desirable to keep the flame hot even beyond its visible part, and everywhere supplied with fresh air. This could be done either by drawing the flame out to a thin sheet, or by shooting across it warm air currents, as in the blow-pipe. Accordingly, the apparatus of Figs. 194 and 195 were constructed. In Fig. 194 *A* is asbestos, on top of which the oil rests, and through which oil trickles to the part below enclosed between pipe, *C*, and surrounding pipe, *B*. The flame having been started at *I*, air was turned on through *C*; the flame was conical, with a well defined blue interior, and was blue even at the tip. This

method of feed might be duplicated by dropping oil in varying quantities on the loosely-packed wick if a variable combustion is desired. This burner can be enclosed and put under pressure, and,

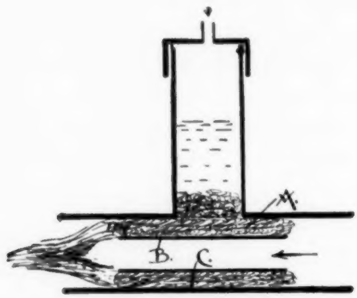


FIG. 194.

moreover, unlike the last, is not sensitive to change of velocity of air through it.

30. While not all the conditions desired are here met, many that are most important are fulfilled. The burner will work, en-

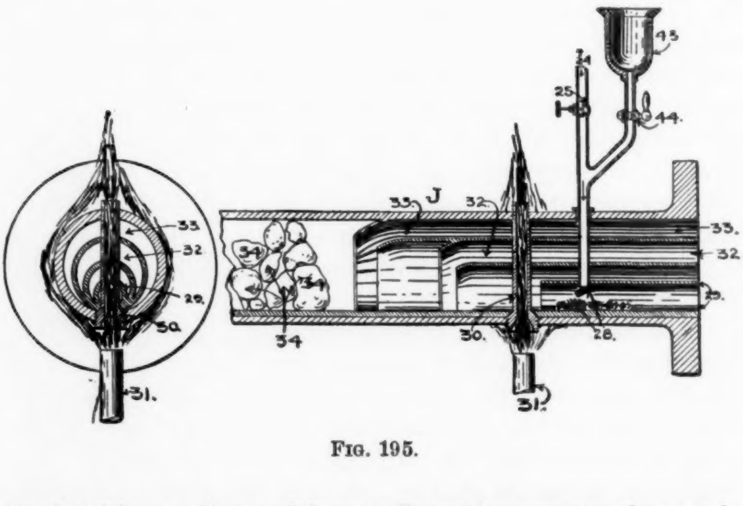


FIG. 195.

closed, fairly steadily, and is not affected by pressure changes, but it always requires a large excess of air, and, therefore, delivers products whose temperature, though fairly constant, is yet not the maximum. Fig. 195 was made to be an advance on this type, by introducing a hot air blow-pipe effect. The flame here, instead of

having a blue centre, has a deep yellow core forced by the air currents into blue at the edges. The centre is the gas generator, which gas is completely burned at the edges by air from the heated lips of the tangent tubes. External heating to redness will cause internal ignition, and wicks placed in the path of the products seem to improve the action, both in completeness of combustion and as re-lighting after extinction. This burner could be used with satisfaction in every point, except that it used such large quantities of air and delivered products of comparatively low temperature.

31. The tendency of the preceding experiments is evident; always away from special vaporizers to arrangements with automatic regulation, the vaporization taking place in the firebox, in the presence of air if possible, and so preventing not only decomposition and carbonization, but also condensation. It seems rather odd that in general the means which worked best under the difficult conditions imposed were in general the simplest. For the use of all oils, including those of low and those of high boiling points, probably the following conditions would, if they could be fulfilled, produce a very good oil fire:

The oil to be introduced as liquid with the air and brought immediately, still with the air, to the hottest part of the fire, with means added to prevent the mixture of the vapor thus produced and its air from mixing with products of combustion of matter already burnt. At the time these conditions were formulated, it seemed impossible that any apparatus could be constructed which would permit of such action; but in fact, such an apparatus was found, and worked so well as to entirely justify all the labor of classification and minute experimental observation, which made it possible to predict what conditions should produce a good method, even when the means seemed impossible to find.

32. This resultant method was not the outcome of this series of experiments alone, but rather of the combined oil and gas experiments, some of which have been previously reported. Just about the time the experiments above described were completed, and the probably necessary conditions for the good oil fire formulated, the explosive gas-fire described in the author's paper, No. 923, Vol. XXIII., p. 292, was discovered.

By the use of the explosive mixture, a fire can be made in a closed chamber, requiring no atmosphere beyond the mixture fed, and such a fire will deliver hot gases at a constant unvarying

temperature, no matter what the quantity burned; this temperature is the maximum possible, as no excess of air is heated; and, finally, this very excellent fire calls for no special apparatus, requiring simply an opening through which the feed must be made at a rate exceeding the rate of propagation, which opening is surrounded by a pile of broken rock. The function of this broken rock is to decrease the velocity of translation by increasing the area of cross-section of the advancing stream, and to increase the rate of propagation of inflammation by heating until these

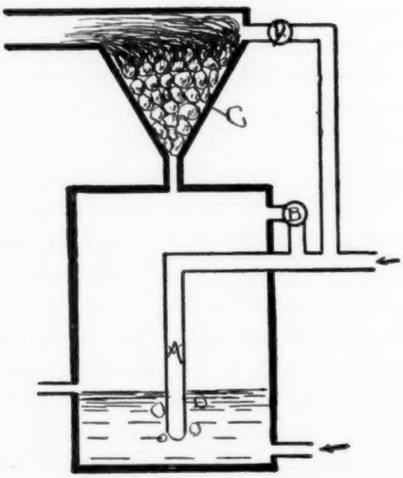


FIG. 196.

two rates become equal, allowing the combustion to localize within the fragments.

33. This suggested a revival of the experiments on oil along the lines laid down as follows: It was desired to vaporize the oil and produce with the vapor an explosive mixture which, in turn, was to burn under pressure as desired in one of the explosive burners. The apparatus in Fig. 196 was constructed to do this; gasolene is held in a chamber kept at about 60 degrees Fahr., and air bubbles through from *A*; the carburetted air was rendered explosive by the manipulation of the by-pass *B*, admitting pure air above the liquid. The resulting explosive mixture was burnt in the explosive-burner, *C*.

34. This arrangement fulfilled the requirements exactly so far as this particular fuel was concerned, giving a fire under pressure

not affected by any changes in pressure however sudden, and delivering at all feeds hot products of exactly the same temperature.

This burner was also piped to the steam-engine and a second by-pass, *D*, permitted, keeping the temperature of the air entering the engine under perfect control. Wide variations of speed and pressure had no effect, neither had the pulsation due to engine admission and cut-off.

35. Here, then, was a very encouraging result, but, unfortun-

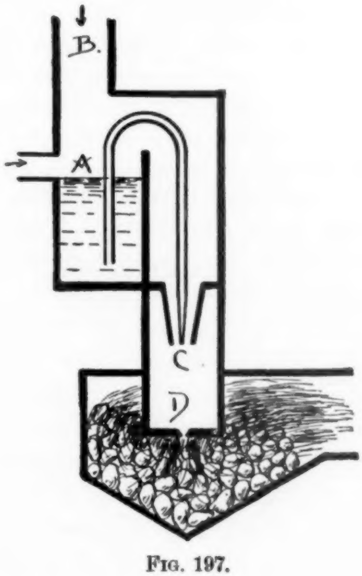


FIG. 197.

ately, only, the fuels easily vaporized, such as naphtha, gasolene, benzine, alcohol, etc., were available.

The next step was an attempt to utilize kerosene in a somewhat similar way. To this end the apparatus of Fig. 197 was set up. Here oil is fed to the chamber *A* and kept at variable level; air is admitted at *B* and passing *C* throws a spray into *D* where it is vaporized by the heat of the fire; the end *D* being covered with the rock an explosive fire resulted, the correct proportion of air to vapor being maintained by varying the air supply and oil fuel.

This, while it worked under some circumstances and gave a very satisfactory fire, showed the same trouble which was experienced with sprays in the other series of experiments and was

abandoned for the device there found to be more satisfactory, *i. e.*, a surface boiling of the liquid. Fig. 198 shows the device constructed for this purpose.

36. Air was admitted at *A*, and with it, at first, some gas, making an explosive fire at *B*. The oil was fed from below to the one under the plate, *C*, heated from above. Varying level

FIG. 198.

exposed more or less surface to be heated and varied the distance from the fire plate. The regulation in practice was not as good as one might expect from the device. The vaporization by approach of the oil to the hot parts suggested the next step, which is so obvious that it seems as if it should have been tried first. This was to simply feed the oil and air through the same pipe to a pile of rock where the explosive fire is maintained, with the expectation that the hot pipe will do the vaporizing. The oil is fed through the cock *A*, Fig. 199, and the air through *B*, both reach the fire through the same pipe *C*, and burn explosively in the

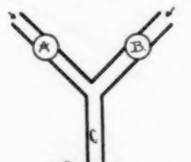


FIG. 199.

mass of rock. This was eminently satisfactory, and showed an action which was very fine, if unexpected.

37. When the feed is slow the pipe *C* becomes hot and then does undoubtedly act as a vaporizer, but when the feeds are increased the fire is forced away from the nozzle, as in the case of gases, and the pipe *C* remains almost cold, no matter how hot the fire in the rocks, but the perfection of the action is maintained

and it is found that not the pipe, *C*, but the hot rocks themselves act as the vaporizer. The air and oil impinge together on the hot mass, spreading out in constant velocity surfaces; the combustion takes place on that surface where the velocity is equal to the rate of propagation and in the passage the oil automatically vaporizes by contact with the same rocks which make the explosive fire possible, and all this happens without diffusion with the products of previous combustion. Thus the function of the rocks becomes complicated; first, starting with gas the explosive fire is made possible by their presence, and the result is the heating of the entire mass from top to bottom, the mass thus heated is a perfect vaporizer for the oil, which, fed with its air makes an explosive mixture and maintains the temperature of the rocks, the whole interrelated series of actions and reactions producing what I have named the "Explosive Oil Fire."

38. Were the proportions not explosive the interior of the mass would chill and the vaporization would stop. It is a very striking experiment to withdraw the nozzle from the intensely glowing mass of rock, of a properly working fire, and note the oil drip, drop by drop, giving off each time a dull red flash and a cloud of smoke, while the whole rock mass cools down; a re-insertion of the nozzle causes at once a resumption of the intense rapid high temperature combustion. And, secondly, by a simple change of proportion observe an instant cessation of the action, producing first smoke and then total extinction.

This method of burning the oil is perfectly adapted to the purpose for which it is designed, *i.e.*, the combustion of any oil in a closed pressure-chamber, as already described, and the action leaves nothing to be desired.

39. Naturally the next question would be to determine the action with residue oils of petroleum. It need only be remarked here that with every oil tried the action was the same; and three fires side by side, burning respectively kerosene, cylinder oil, and linseed oil, showed no difference in action. The so-called residue oils leaves no residue this way. The experiment of feeding the several oils successively through the same fire without interruption resulted in no apparent change of action. We can now see how the action of the brick that Kermode placed on his grates improved the action, which would have been still further improved if the spray had been prevented from diffusing with products before reaching the brick. Moreover, by this simple change

the spraying process would be rendered unnecessary. Also in the case of the saturated mat referred to in the earlier part of the paper, it will now be readily seen how the feeding of both oil and air through the same opening, instead of as designed, would have completely changed the action.

Originally firebrick fragments were used, but the fire was intensely hot, and fused such fragments together, even fluxing them and causing a flow. Later other rocks were tried, and magnesite was found not to fuse; dolomite, also infusible, crumbles slightly.

It was noted in the experiments on gas that considerable gas might be added to a mixture in excess of that required for chemical proportions without injuring the explosive properties of the resulting mixture, which fact was of value in producing surface flames above the explosive fires; of course, there will be a point where the explosive property will be lost and extinction ensue.

40. When an excess of oil was tried the explosive fire between the rock fragments, which act as the automatic non-diffusing vaporizer, was maintained by the lower and explosive part of the fire, while the excess of oil passed on to be burned above. It was found possible to vary the oil 100 per cent. without stopping the explosive action below, the effect being merely a variation in the length of the surface flame. This variation at will in the character of the surface flame is of no importance in the problem which was originally set, *i.e.*, the production of a fire for an internal combustion engine working by the increase of volume at constant pressure. It is, however, of the utmost importance in metallurgical and steam-boiler furnaces, and a few experiments other than those originally set were made on these applications.

41. Fig. 200 shows a series of burners which were used experimentally with success on both open and closed fires, showing the great simplicity that here meets with success. The one at the lower left-hand corner, shows an air chamber of 2-inch pipe through which the oil pipe is led, the air and oil passing downward at an incline of about 30 degrees to the rock bed. Proportions of the mixture are maintained by external valves; the outlets may in this type be easily duplicated.

The one passing the stool shows a down bending quarter-inch pipe fed with air and oil, and provided with a starting gas cock.

About one square foot of rock several inches thick can be kept in a glow with this.

42. To show that the theory of the formation of combustion surfaces holds with this oil fire as with the gas, a pile of broken brick was arranged to run about fifteen minutes, covered with clay; the result is shown on the top of the chair, a round cavity was fused out and a centre lump left, showing what would be expected with

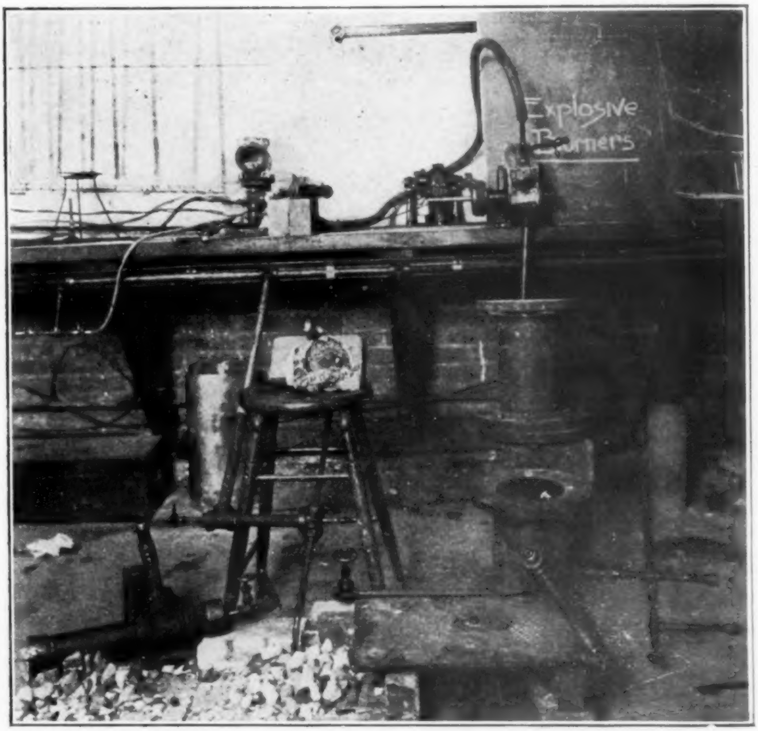


FIG. 200.

this down bending nozzle from the theory, viz., an annular form of combustion surface.

The plate on the floor at the right is tapped to receive from below the nozzle lying on the top containing a centre vertical oil feed surrounded by the air feed. This does not work well on a flat plate as some oil collects in a circle on the plate, where it meets little air, and is moreover chilled by the plate; a conical brick bottom works better.

Two 6-inch nipples arranged for closed fire-pots are shown, the lower one provided with oil, air, and gas inlets delivering to a pipe which merely enters the wall of the fire chamber. This works very well; after heating by a properly proportioned mixture, the whole becomes dazzingly hot, and a blue to orange surface

FIG. 201.

flame several feet high can be obtained without disturbing the action of the lower fire. While the whole fire-pot is white hot and would melt in time, the horizontal feed pipe is always cool enough to be borne by the hand. The very high temperatures that can be produced may be easily estimated when it is stated that this burner can consume a gallon of crude petroleum in about ten minutes, and in so doing uses no excess of air.

43. The upper nipple shown is connected for use with gas, and is provided with a 1-inch clay lining. It is fed from below with a mixture of air and gas from the motor-driven 6-inch positive blower. This was used for melting crucibles of tin, aluminum, lead, copper, etc., in the calibration of a Le Chatelier pyrometer for some experimental determinations of the passage of heat through metal from a hot gas to a cold.

44. In the centre of the shelf is shown a $2\frac{1}{2}$-inch cross, bottom-fed by air and gas direct from the mains and used for heating soldering irons. Kerosene has also been used in this apparatus for the same purpose.

The first application of this method of combustion to a steam boiler is illustrated in Fig. 201. The oil tank in the rear has a delivery pipe starting at the bottom of the tank, and air from the

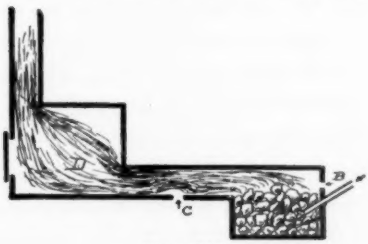


FIG. 202.

main is piped to the oil surface and to the burner through the hose; a slight throttling at the boiler will put enough pressure in the oil to lift it to the burner, where it passes the valve seen in the right front. A half-inch pipe leads to the centre of the firebox and then turns down by an elbow; the grate is covered with clay and the fire-pot filled with broken rock. A gas connection is shown for initial heating and a steam pipe passes from the dome vertically downward in front. It was for observing the action of steam in the fire that this particular apparatus was set up. It was hoped that by the decomposition of the steam in the fire the excessively high temperatures would be avoided and the use of special rock of high fusing point rendered unnecessary. If the fire be started and brought to a steady glow and steam be then admitted, there will at once appear an almost invisible surface flame showing the action desired, a decomposition of steam in the hottest parts and a recombination, more or less complete, beyond at the surface. The steam is thus a sort of heat distributor, and in this way it was found feasible to use common fire-brick; an

occasional sticking together is easily broken up at the end of a run by a bar, and everything made as good as new.

45. It was also thought worth while to try what could be done in producing reverberatory action, similar to that of coal fires. To this end, the apparatus of Fig. 202, was made of brick and clay. With a 5-inch fire at *A*, and an air inlet at *B* and *C*, a good, hot, colorless flame 2 feet long could be produced, heating the chamber *D* to an even glow with an atmosphere reducing or oxidyzing as desired.

It should be noted that all of the explosive burners described will work under any air pressure whatever, a variation merely altering the distance of the combustion surface from the outlet, but for burning a given amount of oil a larger air pipe must be used with low pressure air feeds than with high.

46. In conclusion, it may be said of the method resulting from this experimental research that it seems to be in every way satisfactory for the purpose for which it was derived, and may be of use in other applications. It has no small openings for oil, no possibility of carbonizing; will burn any oil with air at any pressure, provided only that enough air be supplied, and is subject to an almost unlimited variation of form; it will deliver gases at a constant and maximum temperature, which may be lowered to anything desired by air dilution; is capable of burning more oil in less volume than any of the other forms tried, and this with the least possible amount of air. It must be stated as a drawback that without the use of steam it calls for the use of selected rock to prevent fusion.

DISCUSSION.

Prof. A. L. Williston.—I would like to ask what Mr. Lucke used to heat up his broken rock or fire bed?

Mr. Arthur J. Frith.—The description of the experiments of Mr. Lucke, in the simplicity of the final means used, and in the beautiful results obtained, deserve the attention and appreciation of all of us, who are interested in the subject of gas and liquid fuel combustion, and Mr. Lucke is to be congratulated upon the success which has evidently been obtained by arduous and unremitting endeavor. If I may be allowed to make any criticism on the paper it is that it lacks clearness in the description of some of the figures used. Brevity is commendable, but the entire familiarity of Mr. Lucke with his own apparatus is wanting to the

general engineer, and I notice that it takes close reading to clearly follow the text. A word or two of description would, I think, be appreciated. The conditions for successful burning of liquid fuel given in paragraph 31 as "The oil to be introduced liquid with the air and brought immediately, still with the air, to the hottest part of the fire, with means added to prevent the mixture of the vapor thus produced and its air, from mixing with products of combustion of matter already burnt," seems to be not in accord with results sometimes met in the use of atomizers, when, if the oil be not thoroughly atomized, violent explosions result, due, it is believed, to spheroidal action of drops of oil when introduced into an intensely heated atmosphere. Perhaps Mr. Lucke means that this is covered by "still with the air," but I would ask whether the modification, "brought immediately still with the air, gradually to the hottest part of the fire," would not more completely express the conditions necessary for successful combustion. That the burner Fig. 195 and Fig. 199 can burn residual oils without leaving a deposit, which is either stated or inferred from Mr. Lucke's paper, is rather surprising, and I would ask whether Mr. Lucke attributes these excellent results to the presence of air while the oil is vaporizing, to the gradual heating of the oil to successively higher temperatures, with the vaporization of the constituents of the oil in series, so to speak, or to both these conditions combined, and whether there is a complete absence of all deposits in the use of his methods. The automatic regulation of the surface of combustion with varying pressures is very neat, and appeals to us by its simplicity and effectiveness; it appears as if this form of burner is admirable for a steady fire, especially as it is controlled in regard to local heating, and oxidizing and reducing possibilities, but I would inquire what would happen if the velocity of the current should fall below the speed of propagation of the flame, as would happen if an intermittent fire were attempted; would there be any danger of an explosion in the pipe *C*, or would the fire simply retreat to the junction of the pipes *A* and *B*, Fig. 195, and advance again with the increase of pressure? I wish to congratulate Mr. Lucke on having given us a paper which is both interesting and instructive.

Mr. Lucke.—Mr. Frith's suggestion that there is successive evaporation of different constituents of the oil, in other words, that there is fractional distillation going on I think to be very probable. This would be very nicely shown in the difference of

working between crude oil, and, to take a strong case, a lubricating oil; the crude petroleum will start to burn very much more quickly than will a good fuel oil, but a fuel oil, once started, will burn all right.

The combustion is started as follows: Gas is fed into the air current in such proportion as to give an explosive mixture. The surface flame will disappear when this proportion is reached and the fire will jump below the surface; for a moment one can see nothing of the combustion, but soon the glow which exists in the interior will gradually spread through the whole mass. When the mass of rock is properly warmed up the gas is turned off and the heavy oil set flowing. One can start up crude petroleum with just a piece of cotton waste around the nozzle, while benzines, naphthas, crude petroleum, etc., will take fire and vaporize at once, warming up the rocks without preheating by gas, and as the waste burns away, there will be enough heat in the surrounding rocks to keep the residue from forming a deposit.

But if it is attempted to start combustion of a heavy oil with a piece of waste, failure will result. Hence there is no doubt that fractional distillation and successive combustion of parts take place, the lighter constituents heating the rock mass to incandescence first, and preparing the way for combustion of the heavier parts later.

At one time I thought there was a deposit. I was using common red brick, and as is shown in Fig. 200 an annulus was melted out of the broken mass. It turned black in the fusion and I thought it surely was a deposit. Perhaps it was, but it is rather hard to say. However, when I took same magnesite (magnesium carbonate changing to an oxide on heating, which will crumble and get brittle but will not fuse), I found that I could burn oil in the mass for a long time, and the rock would be as snowy white at the end of the run as at the beginning.

If the velocity of transmission were reduced, so as to be less than the rate of propagation, the tendency would be for the flame cap to move back towards the nozzle, and the fire would finally go out, because vaporization would be retarded as the area of hot surface and the temperature of the heated mass were thus reduced; the indication that this action had begun would be a smoky fire.

Mr. Frith.—Would not the flame rush back into the common pipe?

Mr. Lucke.—No. The mixture forms down in the rocks.

No. 937.*

IMPROVED INDICATOR COCK FOR ENGINES.

BY ALBERT K. MANSFIELD, SALEM, OHIO.
(Member of the Society.)

1. It is quite often the case that the steam-pipe line between a boiler and an engine is installed without due judgment, resulting in an unnecessary drop of pressure due to resistances in the pipe line. These resistances are usually caused by too sudden changes of direction of flow, or too high velocity of steam, or both; but what is desired here is to present a means of measuring the

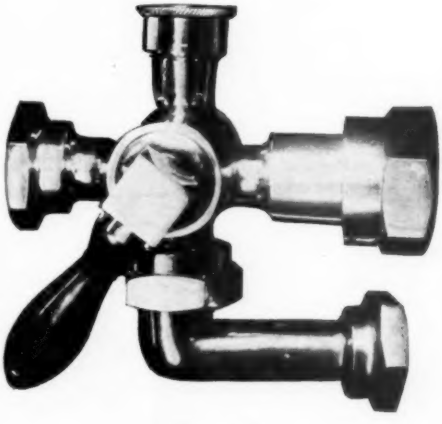


Fig. 203.

drop, or of determining the efficiency of the steam pipe. This consists of the 4-way indicator cock of the illustration, Fig. 203. It is a new device, differing from the ordinary 3-way indicator cock merely in having a fourth connection underneath, which may lead to the steam-space of the engine throttle, or to the exhaust pipe; or, when used on the low-pressure cylinder of a compound,

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* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

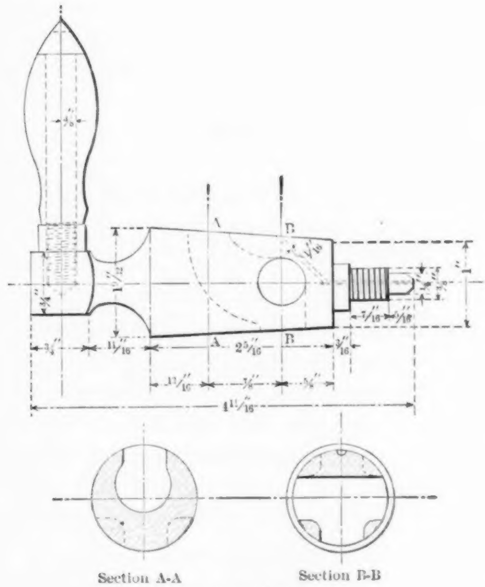


FIG. 204.

to the receiver space. The cock and valve are shown in detail in Figs. 204 and 205.

2. To illustrate its use, a number of indicator cards are here re-

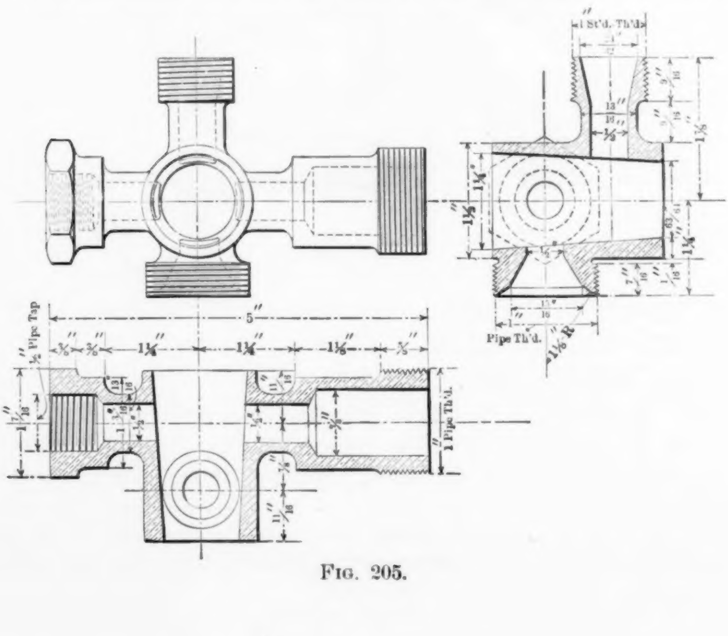


FIG. 205.

produced (Figs. 206-211), which show quite clearly what is meant by inefficient steam-pipe installation. The double-looped diagram above the indicator card is the steam-pipe diagram. The height of the loop measures the fluctuation of pressure in the throttle, or

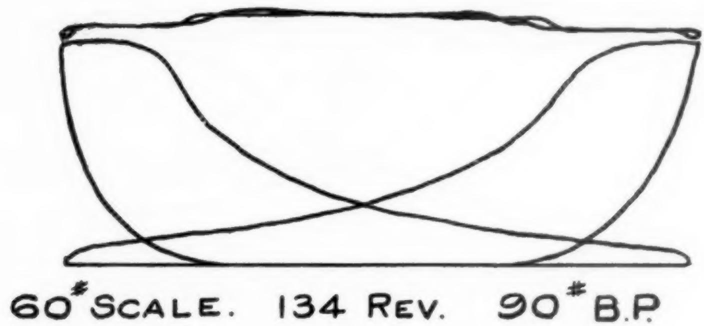


FIG. 206.

in the steam-pipe near the cylinder, while the distance between the lower line of the loop and the top of the indicator card indicates the efficiency of the ports and steam passages from throttle to cylinder.

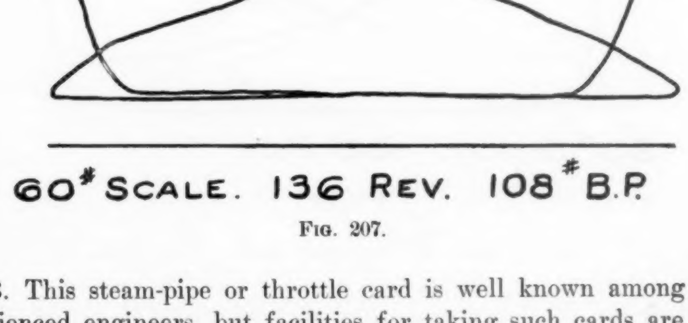
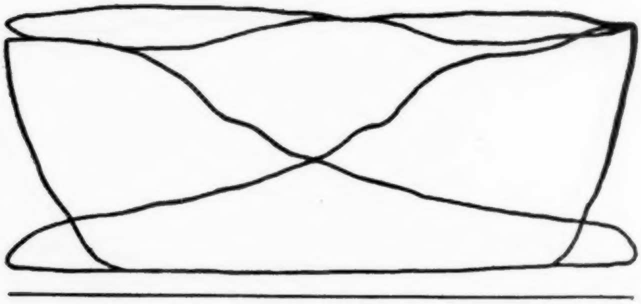


FIG. 207.

3. This steam-pipe or throttle card is well known among experienced engineers, but facilities for taking such cards are not commonly provided. The need of such facilities arises from the fact that in many cases the initial pressure realized in the engine

cylinder is so much less than the pressure at the boiler as to raise troublesome controversy between the purchaser and the builder of the engine.

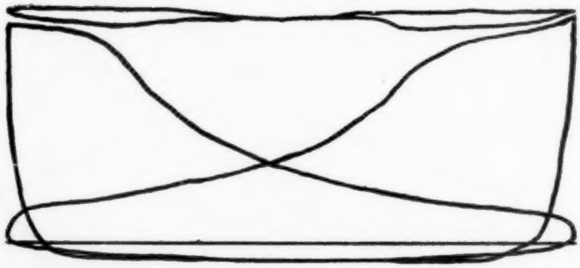
4. This 4-way cock may be applied exactly as the ordinary



80# SCALE. 190 REV.

FIG. 208.

3-way, if desired, the lower connections being removed and a cap nut substituted. When expert tests for economical performance are made, it is commonly best to apply indicators at each end of the cylinder, but notwithstanding this, it is quite usual for general purposes to pipe up so as to enable diagrams to be taken from



80# SCALE. 160 REV.

FIG. 209.

each end of the cylinder on the same card. In piping up for this purpose either with this 4-way cock, or with the ordinary 3-way cock, it is advisable to use long-radius elbows at the ends of the cylinder, in order that the apparent inefficiency of the steam-pipe line shall not be influenced by inefficient indicator pipes.

5. In writing specifications for engines, various phrases are used to express to the engine builders under what pressure of steam the engine is to work. Sometimes the pressure at the boiler is stated, but this makes it hard to fit the engine to the work,

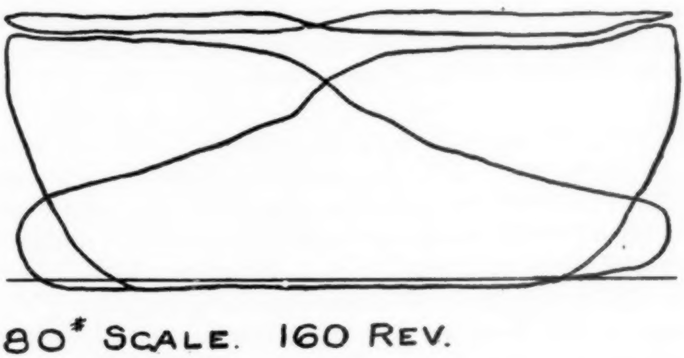


FIG. 210.

considering the fact, as indicated by the above cards, that the realized pressure in the cylinder may be quite different from the pressure at the boiler. Sometimes "pressure at the throttle" is

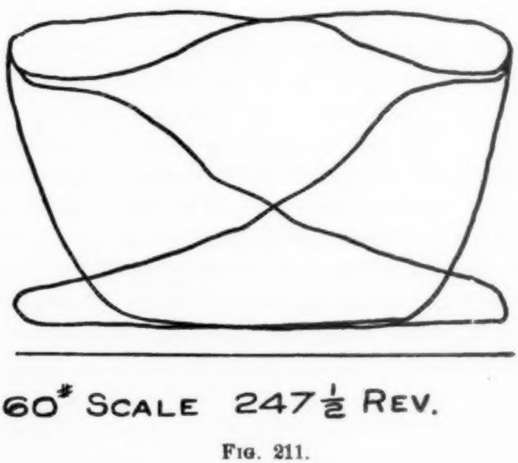


FIG. 211.

referred to, but again it becomes clear from the cards shown that the pressure at the throttle may be very uncertain, owing to resistances to flow between boiler and throttle, which cause the steam to be throttled or wire-drawn into the cylinder, during admission—

that is, up to the time when cut-off occurs. Sometimes the pressure under which the engine is to run is referred to in the specification as "initial pressure," which is also an uncertain quantity owing to lack of agreement among engineers as to what is meant by the term. It appears to be reasonable that if during admission of steam the realized pressure is falling, then expansion is applied to steam of such pressure as occurs just before cut-off, and not to steam of the pressure shown at the beginning of the stroke.

6. Since the best measure of economy in the use of steam is the extent to which it is expanded, and steam of high pressure may be used more economically than steam of lower pressure, therefore it would clearly be unjust to charge the engine with the use of steam of higher pressure than that which is used expansively, providing the throttled introduction of steam into the cylinder is due to causes outside the construction of the engine. Moreover, such introduction of steam handicaps the engine seriously in relation to the maximum load which may be carried. Hence the importance of fixing upon some acceptable measure or definition of the steam pressure under which the engine is working, or is to work.

7. It is suggested that the term "initial pressure" is satisfactory, and that the definition of that term be—the realized pressure in the cylinder just before cut-off begins. It may be objected that this realized pressure is of necessity somewhat lower than the pressure at the throttle at the same instant, but this is to be expected, and should not be objected to unless such difference is great. In good practice it should not exceed about 3 pounds.

8. Of course, when steam pipes are well installed, or when very large steam-pipe receivers are applied to all engines close to the throttle, the need of taking such cards as are here illustrated may no longer exist, but at present the throttle card is often an important witness to the need of more skill in devising the means of delivering steam to the engines without undue loss of pressure.

DISCUSSION.

Mr. Chas. W. Barnaby.—I notice that Mr. Mansfield has failed to bring out one very useful purpose among the advantages set forth by him in connection with pipe diagrams. This is the evidence which they give of the cause of the discrepancy in the

height which is sometimes observed in the cards from the two ends of an engine cylinder. I do not know whether this point has previously been brought before the Society, or is generally understood or not.

In my own experience, I have several times found this discrepancy in heights. The cards would show that the valve events were properly timed, and an inspection of steam ports and passages would show no obstruction at either end of the cylinder. Upon taking a pipe diagram the cause of the discrepancy is revealed; instead of the two loops usually found there are three, as indicated in Fig. 212, showing that the steam pressure at the throttle is at its maximum, *a*, during admission at one end, and at its minimum, *b*, during admission at the other end of the cylin-

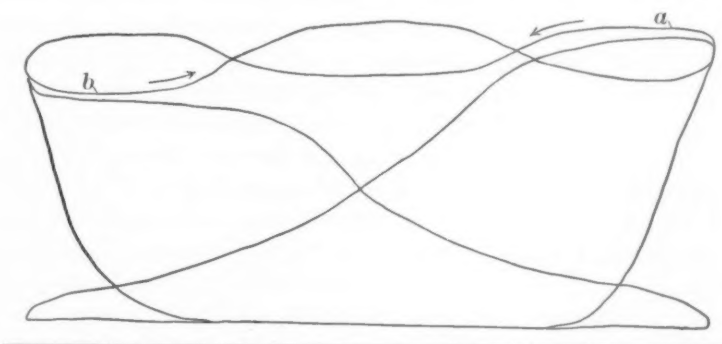


FIG. 212.

der, making as much as 5 pounds or more difference in the heights of the cards from opposite ends of the cylinder.

The only explanation I can give for this result is that the pulsations due to the intermittent flow of steam into the engine cylinder set up vibrations in the column of steam in the steam pipe, and that under certain relations between the volume and length of the pipe, volume of steam admitted to the cylinder each stroke, and number of admissions per unit of time, the natural vibrations of the column of steam are such as will not synchronize with periods of steam admission, the relation being such as to result in three complete vibrations in the column of steam to two admissions of steam to the cylinder, or one revoluton of the engine.

The pipe diagram is usually of the two-loop form, showing a steam column vibration synchronous with the steam admission,

but occasionally the three-loop diagram is obtained as above described. I have, in some cases, obtained pipe diagrams with four, five, or more loops, the even number of loops usually giving equal and the odd number unequal heights of the two cards, although there are exceptions to this rule.

Mr. J. E. Woodwell.—The definition and application of the term "initial pressure," in expressing the working steam pressure of an engine given by the author of the paper, appears to me to be more objectionable than the use of the term "pressure at the throttle," and for precisely the reasons which have been already clearly expressed and are shown by the throttle-pressure diagrams. From admission up to a point near cut-off depending upon the type and design of the valve gear, the steam entering the cylinder is expanding from admission pressure down to the pressure realized before the beginning of cut-off and assumed by Mr. Mansfield to represent the initial pressure of the engine. The particular form taken by the steam admission line is dependent upon a number of conditions, such as the rate of opening and closure of valves and the resistance of steam ports and passages from steam chest to cylinder, all of which are inherent in the design of the engine; and will also be influenced by external losses due to resistance of steam supply piping. The greater the loss due to wire-drawing, the later cut-off will occur in the development of the same power in the cylinder and the less will be the realized pressure before cut-off begins or the "initial pressure" defined by Mr. Mansfield.

The initial pressure of an engine, whether defined as suggested by the author or taken as the average pressure between the admission point and a point near cut-off, will, therefore, be subject to the same effect from imperfectly designed valve gear, ports, and passages as has been shown to result from loss of pressure due to wire-drawing in the steam piping between the engine and boiler.

An accurate definition and an explicit understanding of a term which shall serve as a criterion for the specified working or initial pressure of an engine is necessary both in order to protect the builder of an engine from the results of adverse conditions of steam supply and to enable the purchaser to distinguish between the effect of the latter and that due to imperfectly designed valve gear and steam passages.

As the losses in steam pressure between the boiler and an engine are usually under the control of the purchaser, and those due to the design of the engine to the builder, I suggest as the most con-

venient term for a contract basis that of "pressure at the throttle," defined as the average steam pressure from admission point up to cut-off shown upon the throttle pressure indicator diagram.

In the diagrams exhibited by the author, the "throttle pressure," as defined above, is shown by the lower line of the steam-pipe diagram during admission.

The use of the term "pressure at the throttle," and its determination as described, facilitated by the convenient use of the indicator cock designed by Mr. Mansfield, should result in preventing otherwise unavoidable controversy between the builder and the purchaser of an engine.

*Mr. Mansfield.**—I have never met with throttle diagrams like those referred to by Mr. Barnaby, although I have seen many cases where the initial pressure at one end of cylinder was lower than at the other end, without apparent cause. Mr. Barnaby's sketch is an interesting addition to my collection. Sometimes oddities of the throttle card are due to the fact that more than one engine is drawing from the same steam-pipe line.

Mr. Woodwell's suggestion that "throttle pressure" be taken as the average pressure at the throttle during admission, as revealed by the throttle diagram, appears to me to fall a little short of the best definition. In fixing the dimensions of an expansion engine to produce certain guaranteed results, a designer has in mind some determinate pressure of steam of which the engine will have the benefit. If this pressure is to be subject to an uncertain amount of reduction due to faulty arrangements for conveying the steam to the engine, then the guaranties which would apply to the assumed case would not be suitable to this accidental condition. Hence, may it not be better to define "throttle pressure" as the pressure in the throttle at the time when cut-off begins—that is, when using the term in specifications for expansion engines?

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* Author's closure, under the Rules.

No. 938.*

REPAIRING A BROKEN CYLINDER.

BY H. M. LANE, SCRANTON, PA.
(Member of the Society.)

1. WHEN visiting the plant of the Lackawanna Iron and Steel Company recently, the writer came across a very interesting repair job, and as the methods used in it are applicable to many similar cases, it was thought that a short description of it would be of interest to the members. The history of the case is as follows:

2. The engine was a horizontal blowing engine having cylinders 60 x 100 inches. In 1896 the engineer started his engine rather carelessly, and water in the cylinder knocked out the head, tearing away a portion of the flange on the end of the cylinder and breaking away a little of the casting near one of the ports. In order to repair this the broken portion of the flange was removed and a new casting made for it. A pattern-maker was employed to make a pattern for this, and also a pattern for a brass patch, which was to go over the back of the cylinder covering the broken parts and holding them in place. This patch was about the size of the one shown in Fig. 213. It took the pattern-maker about a week to glue up the stock and work out this pattern. When the pattern was complete a brass casting was made to fit over the broken parts and the new casting which was to replace part of the flange, and holes drilled through the brass into the cylinder. These holes were fitted with reamed bolts, and when the patch was secured in place the edges of the brass were calked down to the cylinder so as to make a steam-tight joint. It would not have been safe to attempt to carry the cylinder head upon this patched flange, and, as a consequence, a strip was secured to the cylinder back of the ports and long studs carried through to this strip, thus taking all strain off the flange. This patching job was very successful, and is still in place. Two years later, in 1898, a

* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

similar accident occurred to the crosshead end of the cylinder, only the break was of a much more serious nature. The entire upper portion of the front end of the cylinder adjoining both ports was broken into more than a dozen pieces. The company wished to get the engine started as quickly as possible. They went to the makers and asked under what terms they could make a new cylinder. The makers asked $1,000, and could not furnish it short of two or three months. As a consequence, the repair gang was set at work to see if they could not fix the cylinder.

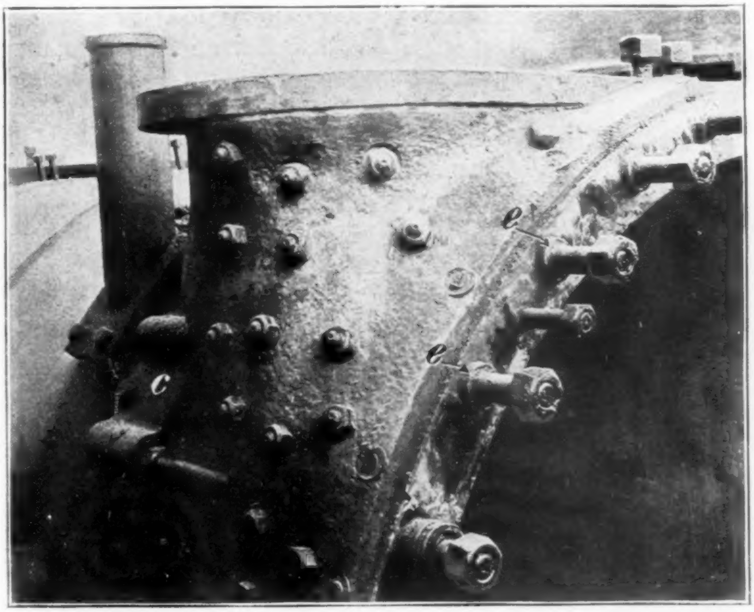

FIG. 213.

3. Mr. A. H. Lee, who is in charge of the blast furnace plant of the company, planned out a method of repair which proved very efficient. His experience of two years previous with a wooden pattern had shown him that this method was slow and costly. As a consequence, he simply placed the broken pieces together, blocking them in position as well as possible. He then had one of the bricklayers of the repair gang arrange a clay patch over the broken parts. It was desired to make this clay patch just one inch thick at all points, and to accomplish this one-inch brads were forced in until their points came in contact with the iron, and the

clay was cut down flush with their heads. After the patch was in place, a rough wooden box was arranged about the end of the cylinder and a plaster cast taken of the same. As soon as it was hard this plaster cast was removed, the clay cleaned off, the inside of the plaster cast and the cylinder treated with a coat of oil, the plaster cast returned to the cylinder and plaster of Paris poured in between the outer cast and the cylinder, thus forming a plaster of Paris pattern of the desired form. The port, shown in Fig. 213, was of such a form that a single pattern could be made which would draw from the sand freely. In the case of the port

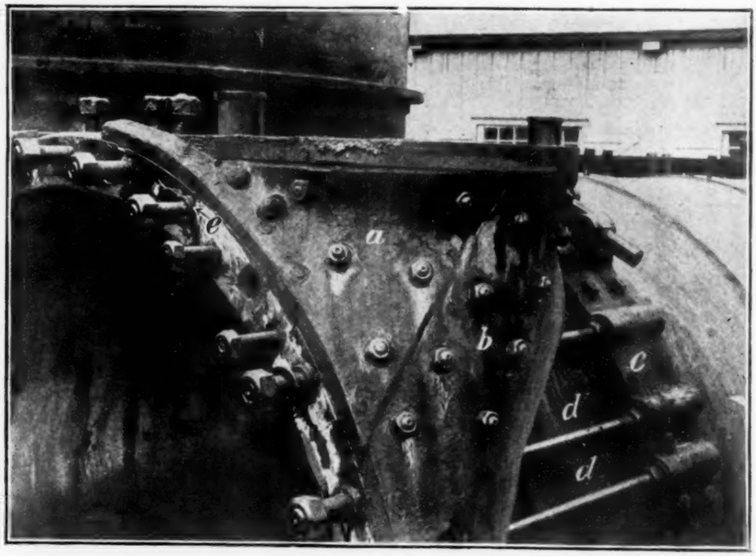

FIG. 214.

shown in Fig. 214, the break was of such a character that it would be impossible to make a single pattern which could be drawn from the sand, and, hence, a piece of tin was inserted while pouring the patterns, and two patterns, *a* and *b*, made. After the plaster had hardened the outer cast was removed and the plaster patterns removed from the cylinder.

4. It was foreseen that shrinkage along the line between the castings *a* and *b* would result in opening this space, and, as a consequence, wooden strips were attached to these edges of the pattern. While it took the pattern-maker a week to make the pat-

terns for the head end of the cylinder, all of the patterns for the crosshead end of the cylinder were made in less than a day. These plaster patterns were then taken to the foundry and brass castings made from them. It was found that these castings fitted the cylinder very closely, and a small amount of filing and scraping brought them to a remarkably good bearing. After this, two or three holes were drilled through each casting and the cylinder and rough bolts put in. Other holes were then drilled and reamed and fitted bolts placed in them, and finally the holes containing the rough bolts were reamed and fitted bolts placed in them. The boilermaker was then called upon to calk the joint between the castings *a* and *b*, Fig. 214, and the edges along which the castings came in contact with the cylinders.

5. In order to relieve the flange from strain as far as possible, the strips, *c*, Figs. 213 and 214, were secured to the cylinder back of the ports and long studs, *d*, carried from these strips through the ports and cylinder flanges to the cylinder head. These studs were turned with collars, as shown at *e*, which would serve to hold the flange in place. As a further precaution, the new cylinder head was made thicker than the old. The cylinder in its patched condition did not leak at all when steam was turned on, and has been in use for three years. It has now been removed from its old setting, and will be used with its engine in a new location. When the brass patches were placed upon the cylinder the space beneath them was filled with Japan filling, so as to aid in making them steam tight and in giving them a good bearing. All of the breaks at both ends of the cylinder occurred in the counterbore and ports, none of them extending into the portion of the cylinder over which the piston travelled. The engine was actually shut down three weeks during the second repair job. This was a considerably longer time than was necessary; but after the repair gang had made sure that they could mend it on short notice, work was not pushed so rapidly as to interfere with their other duties.

No. 939.*

SOME DETAILS OF DIRECT-CONNECTED GENERATOR SETS.†

BY WILLIAM H. BRYAN, ST. LOUIS, MO.
(Member of the Society.)

1. THE results of a recent investigation into some details of the design and construction of Steam-Driven Direct Connected Generators, may be of interest. The inquiry covered:

First. The procedure usually followed between the builder of the generator and the builder of the engine in reaching an understanding regarding the detailed design of shaft and bearings.

Second. The method of construction and final erection preferred.

Third. The advantages and disadvantages of a shaft coupled by flanges, as compared with a continuous shaft.

Correspondence regarding these points was conducted with a number of the leading engine and generator builders, and was supplemented by personal interviews as opportunity offered.

2. There seemed to be a practically unanimous agreement to follow the general design and dimensions recommended by the Society's Committee on Standardization of Engines and Dynamos in its final report at the New York meeting, December 1901. Pending the adoption of these rules, however, or where for any reason the case seems to demand special consideration, the following procedure is usually followed:

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* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For further references on this subject see *Transactions* as follows:

Vol. xx., p. 758: "Standards for Direct-Connected Generating Sets." J. B. Stanwood.

Vol. xxii., p. 520: "Preliminary Report of Committee on Standardization of Engines and Dynamos."

Vol. xxiii., p. 99: "Final Report of Committee on Standardization of Engines and Dynamos."

On receipt of the order at the works of the generator builder, a certified dimension print is prepared, giving the data which the engine man needs to design his shaft. This drawing shows:

A. The limit lines beyond which the engine parts must not extend.

B. The form which the shaft should have within the armature spider.

C. The weights of revolving parts.

D. The unbalanced magnetic pull for 1-32 inch displacement which might result from the armature getting a little out of centre, by the wearing of bearings or otherwise.

Usually the diameter of the shaft is left wholly to the engine builder, after putting him in possession of the data necessary to design the same intelligently. The custom is now almost universal of supporting the brush holder rigging on the generator frame, so that the engine builder is relieved of any responsibility on that account. As a rule, also, the engine builder furnishes the extended base, outboard bearing, holding down bolts, and shaft keys.

3. The unbalanced magnetic pull (paragraph *D* above) is of decided importance, and its possible effect must not be overlooked. This pull may, of course, be in any direction in the plane of revolution, and it varies as the square of the displacement. It must be considered in determining shaft dimensions and bearings, as it may occur in a vertical plane, and thus have the same effect as additional weight of armature. It may also occur in a horizontal plane, and must, therefore, be considered in designing the bed plate and foundation bolts.

Usually the generator builder makes his armature hub sufficiently thick to provide for considerable variation in the diameter of the shaft, as may be required by different engine builders. If for any reason the generator builder has already fixed the bore of the armature the engine builder is expected to meet that condition. If he cannot readily do so, the matter is one which must be taken up further for adjustment, or settled by the purchaser or his engineer.

4. On receipt of the above data, the engine builder is supposed to proceed at once with the design of a shaft suitable for the intended work. When completed, his drawings are forwarded to the generator contractor for checking and approval. On receipt of approved drawings the engine builder proceeds with the construction of the shaft.

As soon as possible after receipt of the shaft dimensions from the engine builder, the contractor for the generator prepares a pin gauge giving the exact dimensions of the bore of the armature hub. There is a general acquiescence in the recommendation of the Society's Committee that the engine builder make the necessary allowance for the press fit. A few builders, however, advise that the generator contractor provide the allowance when making the gauge, so that it will show the actual diameter to which the finished shaft is to be turned. In justification of this position they claim that the allowance depends far more on the material of the armature and the design of the hub, than it does on the shaft. In most cases the allowances recommended by the Society's Committee for shrink fit are considered ample, although one prominent generator builder thinks the allowance should be doubled.

5. Sometimes there is a departure from the above plan of procedure to the extent that the one whose work is furthest advanced makes the pin gauge, and sends it to the other, who governs himself accordingly.

Although all generator builders claim, in advance of award of the contract, that they are prepared to furnish generator data to the engine builder almost immediately on receipt of order, there is almost invariably a serious delay in reaching an agreement between the two contractors. This loss of time is sometimes due to the necessary "red tape" through which an order must pass before it reaches the construction department. Sometimes it is claimed to be due to delays in the mails. Sometimes the data is withheld pending the execution of the formal contract by the proper officials. These delays are often serious when the work is of the "rush" order, and it seems that an effort in good faith should be made to avoid them. Is there any good reason why full data on standard machines—even including shaft gauges—should not be kept on hand at the district offices for immediate delivery to the engine builder on award of contract? It has even been suggested that bidders on generators be required to file with their proposals the necessary shaft data. This would save much vexatious delay. It is, of course, presumed that the speed of rotation has been decided upon and agreed to by both parties when the contracts are closed.

6. When the engine contractor returns his drawings of the shaft to the generator builder the following information is supposed to be given:

E. Direction of rotation—whether clockwise or opposite—when looking at the commutator end of the machine.

F. Location of the generator with reference to the engine, whether the commutator is on the right or left of the generator when standing at the cylinder and facing the shaft.

G. Further details, such as whether there are one or more cranks, whether they are solid forged or forced on, height of centre of shaft above floor, diameter of shaft, location of armature and fly-wheel in relation to bearings, dimensions and weight of fly-wheel, length of hub and cross section of rim.

Some difference of opinion exists as to the best method and place of erecting the armature on the engine shaft. The ordinary practice for small and medium sized units is for the engine contractor to place the shaft in final position where the unit is to be used, after which the generator contractor presses on the armature, and completes the adjustment of the electrical machine ready for service. This necessarily involves some extra expense when the point of erection is at some distance from the builders' shops, or where they have no local erecting gang. Furthermore, the work is always more expensive, and can never be as satisfactorily or as quickly done, as in the shops of one or the other of the builders. There is a widespread sentiment, therefore, that either the generator contractor should send his armature to the engine shops where it can be placed on the shaft by the engine builder; or that the shaft itself—in whole or in part—be shipped to the generator builder for the armature to be pressed on, the latter arrangement seeming the preferable one. This plan possesses many advantages, but is open to the criticism that extra freight charges are incurred, and delays invited.

7. The relative location of the two shops with reference to the point of final use would seem to be a factor in determining which shop should press the armature on. For a set destined for erection in St. Louis, for instance, the engines being built at Springfield, Ill., and the generators at Schenectady, N. Y., it would not be justifiable to ship the engine shaft to Schenectady, and return. The fact that as soon as the armature is attached to the shaft the whole becomes electrical apparatus, and takes a higher freight classification, has a bearing on the subject; also that there is an increased freight cost in dividing shipments instead of concentrating them. The contracts should state definitely who is to pay the increased freight charges.

Trouble often results from the erection of the armature on the engine shaft at a distance from the shop, where competent men and suitable facilities are not always to be had. This is particularly the case with centre crank engines, where the crank pin may be sprung, unless a piece is fitted between the jaws of the crank before the pressure is put on.

8. Several prominent builders recommend mounting the armatures on conical collars instead of the usual press fit. This is claimed to lessen the time of erection, obviate the chances of springing the shaft, and remove all danger of misfit. Furthermore, if the owner ever desires to remove the armature, it becomes a simple and inexpensive matter. On the other hand it is claimed by many large builders that the press fit is more rigid, distributes the strains better, is less expensive, and, everything considered, is superior.

9. For many years I have specified that the engine shaft carrying the armature should be continuous, and not coupled by flanges or otherwise. This arrangement seemed to have the approval of the best engineers and builders on account of its superior rigidity and reliability, as well as the space required on the shaft. It is still preferred by most of the largest generator builders, although many of them do not object particularly to the coupled construction. Sometimes the use of the solid construction involves delay in getting the necessary forgings, as well as extra cost, if it is a rush order. Ordinarily, however, the coupled construction is the more expensive one, but some time may be saved by its use. I was surprised to find a large and growing sentiment among builders of centre crank engines in favor of the coupled form of shaft, the argument being substantially as follows:

10. The armature shaft being a short and simple structure could readily be sent to the generator shops for the armature to be pressed on, freight and boxing both being less. Time could always be saved, as it would only be necessary to fit the shaft, adjust it centrally in the outer bearing, then box and ship it, the main shaft being retained to complete the work of balancing, polishing, etc. There will be no danger of springing the shaft, as explained above. Earlier delivery of the complete engine could usually be made, as the engine shafts could be made in quantities, and kept in stock. When time is short the engine builder could complete all his work, except the extended shaft, whereas there is often a delay if a continuous steel forging is necessary. The entire engine

can be completed—and even tested—while waiting for the forging for the armature shaft, which on arrival can be finished up in a few days. Some builders are preparing to make up a stock of crank shafts with flanges finished solid on the end of the shaft ready to receive the flanged armature shaft, which will be specially constructed in each case to fit the generator selected. The saving in time and expense is obvious.

I have not been able to satisfy myself, however, that a coupled shaft is as desirable, everything considered, as the solid one, as the chances for inaccuracy and derangement appear greater. The increased space required is also often important, particularly in city plants. There is room for argument on this point, however, and the hope for a full discussion is my principal incentive for presenting this paper.

11. Is the overload limit of 25 per cent. recommended by the Committee wise? Most generator builders now guarantee their standard machines to safely carry 50 per cent. overload for one hour or longer. Should not the engine have a similar margin? Often the peak of the load lasts but an hour or so, and it is better engineering to run at reduced efficiency for this short period, rather than to invest a greater amount in a unit which will be underloaded for the rest of the 24 hours. This can be accomplished by a later cut-off, if the engine is structurally strong enough. Part might also be gained by running up the steam pressure a little, but this is not always permissible.

It is to be hoped that engine and generator builders will promptly carry out their agreement as to early compliance with the details established by the Society's Committee on Standardization, and that there will result great shortening in the time now necessary to agree on shaft data. May the day speedily come, also, when a similar agreement may be reached as to standard sizes of alternating and railway generators.

DISCUSSION.

Mr. J. B. Stanwood.—Mr. Bryan's paper is of interest to those of us who labored with the problem of Standardization of Engines and Dynamos, and it gives great satisfaction to learn that there is a practically unanimous agreement among manufactures to follow the recommendations of the Society's Committee. An influence which would contribute largely to the more general adoption

of these standards would be the general use by consulting engineers and architects of these recommendations in their specifications.

The scheme of standardization seems to depend to a great extent upon the establishment of standard sizes for the armature bores. With these bores well fixed for different sizes of units and for the two classes of engines—centre-crank and side-crank—the dynamo builder is enabled to manufacture his armatures in quantity, thereby cheapening the cost and facilitating the delivery of the generators; the engine builder is in a similar position with his shafts, for the forgings, especially those for centre-crank engines, can be kept in stock in anticipation of orders, and the finished length and fit can be made on short notice after the entire engine is built.

To the Committee it seemed more practicable that the generator builder should fix the bore and that the engine builder should work to gauges furnished. This especially is necessary where the armature bore is sized by standard plugs to which the hole is scraped straight and to size. The engine builder can more easily grind the shaft to a fit than the hole can be bored and scraped to a gauge.

As to the character of the fit, the Committee selected a shrinkage which would be as small as possible, yet sufficient to insure that the armature should be at least tight on the shaft. Some generator builders have written me that they will use only one armature casting, and that large enough to fit the larger shafts of side-crank engines; then, for the smaller centre-crank shafts, they will bore out the hub for conical collars fitting the smaller shafts; by this means they have only one armature casting for both the side and centre-crank shafts.

Whether the shaft should be continuous or not, is a matter which the Committee did not feel called upon to decide. If the above arrangement of one bore and conical collars is found to be practicable, the centre-crank shafts, which have to be handled with care, will need no press fit, and, therefore, need not be in sections. The side-crank shaft, whch should not be in sections, can be more safely pressed into the armature at the place of erection, if so desired.

As to overload, the Committee considered that a too large overload capacity would tend to low economy in the engine. With some types—notably non-condensing compounds—the maximum load is nearly the most economical one, so that to call for great

overload engine capacity would compel engines of this class to operate a large portion of the time at low rates of economy.

There is a difference in the character of engine and dynamo capacity. With an engine, if the capacity is there for short periods, it is there for long periods (if structurally strong enough). With a dynamo a short, heavy overload can be safely maintained, which, if prolonged, would prove dangerous. In view of this difference, it would appear to be good practice to have, as a matter of safety, the generator capacity at any rate greater, as is usually the case, than that of the engine.

Mr. Walter M. McFarland.—As a member of the Committee on Standardization of Engines and Dynamos, I am naturally much pleased to note Mr. Bryan's remarks in Paragraph 2 of his paper, where he says that his investigation has shown that there is a practically unanimous agreement to follow the recommendations of the Standardization Committee. This, of course, we had every reason to expect from the statements made to us by builders of engines and generators with whom we were in constant touch during the sessions of the Committee.

The remarks in Paragraph 5, with respect to the matter of delay in the mutual agreement of the engine and generator builders about shaft data, speed of rotations, etc., seem to me to show the importance of the work which the Committee did, and also that when it is generally understood that direct-connected sets will be constructed in accordance with the standards recommended by the Committee, there will be no further excuse for the delay.

It seems to me hardly admissible for district offices to have the final decision with respect to some of the items discussed in Paragraph 5, and especially for the district offices to have the shaft gauges on hand. Their normal work is so entirely different from this question that I fear, where we are working with differences of a few thousandths of an inch, trouble would arise. It seems to me that these gauges ought always to be sent directly from the shop.

On general principles, I am certainly disposed to agree with Mr. Bryan that the continuous shaft is preferable to one with a coupling, but, like him, I believe it would be beneficial if there were a full discussion of this particular point, the discussion naturally taking the shape of a presentation by the advocates of the coupling of its advantages, and how assurance can be given that there will be no danger of lack of alignment. There is, of course,

the objection that even couplings forged on the shaft take up more room than a continuous shaft, and separate couplings, forced on, still more. In any case, the couplings should certainly be male and female. The problem is mainly for the engine builder, but the builder of the generator is naturally interested that no scheme shall be adopted unless it guarantees alignment and ample rigidity to guard against undue deflection. In the case of these small combined units, it often happens that the generator builder has to take the contract for the whole unit, engine as well as generator, so it is important that the views expressed should insist upon a method which will insure the integrity of the shaft.

With respect to the question of over-load limit in Paragraph 11, it should be noted that the recommendations of the Committee in Paragraph 10 of its report were entirely at the request of the engine builders. As Mr. Bryan correctly states, dynamo builders are prepared to guarantee an over-load capacity of 50 per cent. for an hour or longer, and it would have been entirely agreeable to the members of the Committee representing electrical firms to have had such an over-load rating. I am sure that if the engine builders, on further consideration, care to have the Committee's report amended so as to allow 50 per cent. as the over-load, there would be no objection on the part of the Committee.

Mr. W. D. Forbes.—I regret that we have not time to go into this paper a little more fully, but as a member of the Committee referred to, I wish to say a few words.

The paper is practically an admission that we cannot bore holes as truly to gauge as we can turn shafts. This matter of holes in armature spiders is a daily source of trouble to me. When I first began connecting engines and generators, and received the gauges of the armature bore from the generator builders, I used them and made a shaft at once to the gauge before I found out when I got the holes I had to make another shaft to fit them. I think one trouble is that the holes in the spiders are strained when using the testing shafts. I cannot understand the necessity of these pin gauges. With the magnificent work which we get from a man like Mr. Bond, why with his standard gauges cannot holes be made to them, and we certainly can make shafts to fit standard gauges.

Among the great engineers who are the figures in this Society I am but a cipher, and my opinion is of but little weight, but I wish to call your attention to the value of our discussions. They

are, in my opinion, extremely instructive, and of as much importance as the papers themselves, as they bring out the differences of opinion; but I wish to say positively that I think we are going wrong when these discussions cease to be mental and become personal.

Mr. William Kent.—Mr. Bryan asks, "Is the over-load limit of 25 per cent. recommended by the committee wise? Most generator builders guarantee their standard machines to safely carry 50 per cent. over-load for one hour or longer. Should not the engine have a similar margin?" I have run across something lately which seems to indicate why the engine builders specify 25 per cent. over-load instead of 50 per cent.. It is entirely a matter of the price of the engine. If a man wishes to buy a 250-horse-power engine he ordinarily thinks about the price; the man who puts in the smallest engine will be able to name the lowest price, and the smallest engine will carry the smallest over-load. It is the same reason which induced the boiler makers of the country to change the amount of heating surface per horse-power from 12 to 10 square feet, and in some cases to 8 square feet or less; that is, to make a smaller boiler in order to meet competition. I hope the Committee will take a stand against that, so that an engine rated at a certain horse-power at its most economical load will be capable of running at 40 per cent. or 50 per cent. over-load.

Mr. Forbes.—What is the use of calling an engine 50 horse-power and then making it 75? In the United States Navy they ask for $33\frac{1}{3}$ per cent. over-load. I asked the officers why that was. They said, if a shell strikes us, we may want a little extra power. Nobody knows what is going to happen when a shell strikes a ship. It may result in a 500 per cent. overload. I cannot understand why we should have any over-load. Sell things for what they are and call them what they are.

Mr. Kent.—I am glad to answer the question directly. A man wants to run his factory with say 250 horse-power during the day. He wants to put on 100 horse-power extra for lighting while working at night. That is the case, I think, the engine builders ought to meet. While it has been said that 50 per cent. over-load cannot always be reached on an engine which gives its rating at an economical load, 40 per cent. over-load may be reached, or 30.

Mr. Forbes.—Then sell it for just what it is; sell it for a 75-horse-power engine. Do not call it 50 and then say, no, it is something else.

Mr. Kent.—From time immemorial the custom of the country has been to sell boilers and engines on that understanding—that they are to be rated at the economical load, but to have a capacity for over-load. Why do we want to change that and say that an engine rated for 100 horse-power will give no more than 100 horse-power?

The Boiler Test Committee recently reported as to boiler ratings that the rating of the boiler should be that capacity at which it would show good economy, but that it should be capable of developing at least one-third more than the rated capacity when the full draft is used and the fires crowded. Why should not a similar method of rating be used for engines?

*Mr. William H. Bryan.**—I am glad to note the continued interest in this subject. Admitting that improvement has been made, there is room for further advancement. Too much time is still lost while the engine and generator contractors are getting together on shaft details. It seems to me that Mr. Forbes's point is well taken—that this work could and should be done accurately to gauge. Certainly an important advantage will be gained when engine and generator builders can carry their standard machines in stock, ready for immediate assembling.

If coupled shafts are to be used, however, why should not the generator builder furnish the shaft rigidly secured to armature, ready for engine coupling and outboard bearing? Would not this greatly simplify and expediate the work?

The proper horse-power rating of an engine has not, it seems, received exact definition by competent authority. Cylinder dimensions, speed, and initial pressure do not tell the whole story. The most efficient point of cut-off, the latest cut-off, and the structural strength and wearing qualities of the machine are equally important. The rating of a dynamo has been established by the best practice to be that capacity at which its efficiency will be the maximum, and at which it can run continuously without distress. It must be capable in emergencies of developing from one-third to one-half more for short periods without injury. The same is true for boilers. Is there any reason why engine ratings should not be governed by substantially the same requirements? Efficiency is sacrificed in both generators and boilers when overloaded, and the same is permissible in engines. It is, of course, good practice to have the capacity of the engine slightly lower than that of the

* Author's closure, under the Rules.

generator, so that it will slow down and protect the unit in the event of serious over-load. It is folly, however, to purchase a generator capable of carrying 50 per cent. over-load for an hour when its engine cannot pull it. While it is true in the abstract that if an engine can carry an over-load at all it can do so continuously, the fact remains that we do not hesitate to overload engines for short periods to an extent which we would not for a moment contemplate carrying on them continuously. In my specifications, of late, I have been calling for one-third over-load, and have no difficulty in securing proposals.

It is to be hoped that engine builders will find a way to meet these over-load requirements. In the meantime, engineers and architects should be urged to adhere to the Society's code when writing specifications.

No. 940.*

ELEVATOR SAFETIES.†

BY CHARLES R. PRATT, MONTCLAIR, N. J.
(Member of the Society.)

1. In my paper on Elevators presented at our meeting in Washington in May 1899, vol. xx, No. 820, p. 804, I described two devices (Figs. 215, 216, and 217) which up to that time were the best known means of stopping an elevator car by gripping steel guide rails. These two devices were then so far superior to anything else that had ever been used for this purpose, that their defects, while well known to the author, were not fair subjects for criticism. Now, however, as these two devices represent the two general principles common to all methods of gripping a steel guide rail, their defects must be described in order to show why and how they have been overcome.

2. In the first place, let the author confess, with due humility, that there is probably not one man, with a well-balanced mind, a due regard for his life, and a thorough knowledge of elevator safeties, who would get in an elevator car and have the ropes cut and depend upon any of these aforesaid safeties to let him down easy. And while I am not, at the moment of writing, prepared to say that I am willing to prove the reliability of my latest type of safety, by being in the car when the ropes are cut, I can report unofficially that the draughtsmen, the foremen, and machinists, do this for fun when I am not around to prevent it, which is a tribute of confidence never paid to any other elevator safety. I cite these incidents to show the necessity for improvement in this very important function of protecting the lives of the millions of people who daily ride in elevators. And the fact that elevator accidents are of rare occurrence, is no excuse for

* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For further references on this subject see *Transactions* as follows :
Vol. xx., p. 804 : "Elevators." Chas. R. Pratt.
Vol. xx., p. 629 : "The Plunger Elevator." Geo. I. Alden.

inadequate means of stopping the car in case of any accident to its hoisting apparatus.

3. Owing to the fact that nearly all elevator accidents are due to failure of the hoisting machinery and not to the breaking of the ropes, and, therefore, the car speed accelerates too gradually to slacken the ropes sufficiently to operate a safety by means of slack hoisting ropes, the safety must be operated by some form of speed governor. The next consideration is, with what shall the device on the car engage to stop its fall easily? My former paper on Elevators described about all the different means used for this purpose, and experience seems to prove that the guide rails, wood or steel, are the best supports for a gripping device on the car to engage. Experience also shows that a centrifugal speed governor is the best means of operating the safety.

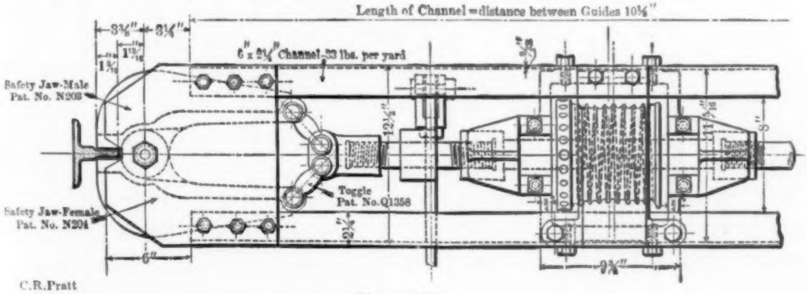

FIG. 215.

4. We have then as a base of operation:

(1) Centrifugal force, absolute and controllable.

(2) Steel guide rails, of ample strength, smooth and well lubricated.

(3) Power to grip the rails, either by the travel of the car, which is absolute and unlimited for this purpose, or by the stored energy of springs, which is limited. These are certainly ample means to accomplish with absolute reliability the function of stopping an elevator car easily when it is otherwise free to fall. To what defective mechanism then is due the fact that this has not yet been accomplished, except by the device which will be described later on in this paper.

5. Reference to Fig. 215, will clearly demonstrate one radical defect in one device, viz: The gripping power in this instance is applied entirely by the travel of the car, revolving a drum by means of a rope which is gripped by a centrifugal gover-

FIG. 217.

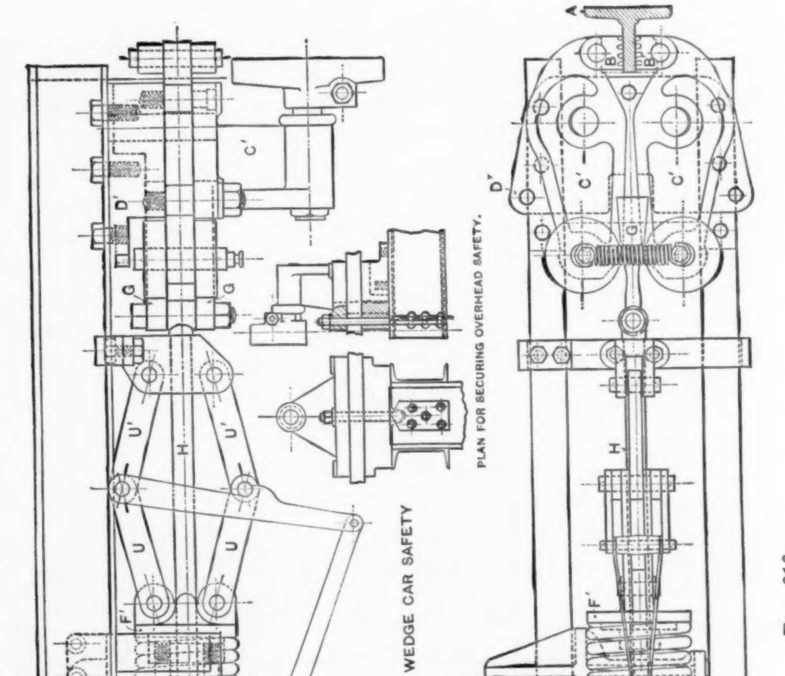

FIG. 216.

nor secured to the hoistway beams. This drum revolves a shaft having a right hand screw on one end and a left hand screw on the other end. Nuts on these screws engage toggles, which engage levers which grip the rails, as shown in Fig. 215. Consider now what occurs when the car, through excess of speed, sometimes as high as 800 or 1,000 feet a minute, causes the centrifugal governor to operate and grip the rope which revolves the drum. First, the necessary clearance, at least 1-8 inch between ends of levers and guide rails, must be overcome, and more than one revolution of the drum is required to do this, anywhere from 4 to 8 feet travel of the car in actual practice is necessary to bring the ends of these levers in contact with the rails, and the speed may then be 1,500 feet per minute. Secondly, when the ends of these levers come in contact with the rails, if the car speed is to be gradually reduced through a sufficient distance to avoid injury to the passengers, the car must continue to travel, the drum to revolve, and the levers to bend, until that distance is overcome. Can toggles be adjusted, and the wear of the levers on the rails be compensated for to accomplish this as a practical device? Most certainly not. What actually happens is a permanent set to the levers as they are bent, and a stop in such a short distance that broken legs and ankles usually result from it. And if not readjusted or repaired, after a few operations at high speed and heavy load, it becomes inoperative.

6. Reference to Figs. 216 and 217, will demonstrate the defects in one other device, and here the author criticizes his own design: The defects in this type of safety are the limited power of the spring and the suddenness of its stop with light loads, the severity of the hammer blow with which the spring operates the safety, and the consequent lack of durability. The limited power requires frequent inspection and adjustment to keep it in operative condition. When such inspections and adjustments are faithfully and competently made, the safety is reliable, and grips the rails instantly when the normal car speed is exceeded, and never stops the car suddenly enough to injure the passengers, although its stop with a light load is not a comfortable one. About 25 operations without adjustment would make this safety inoperative, and 1-32 inch wear on the jaws, which occurs when the regular guide shoe is allowed to wear too far, will also make it inoperative. We have, therefore, defects in both of these devices which preclude their claim to being adequate safeties to stop an elevator, with

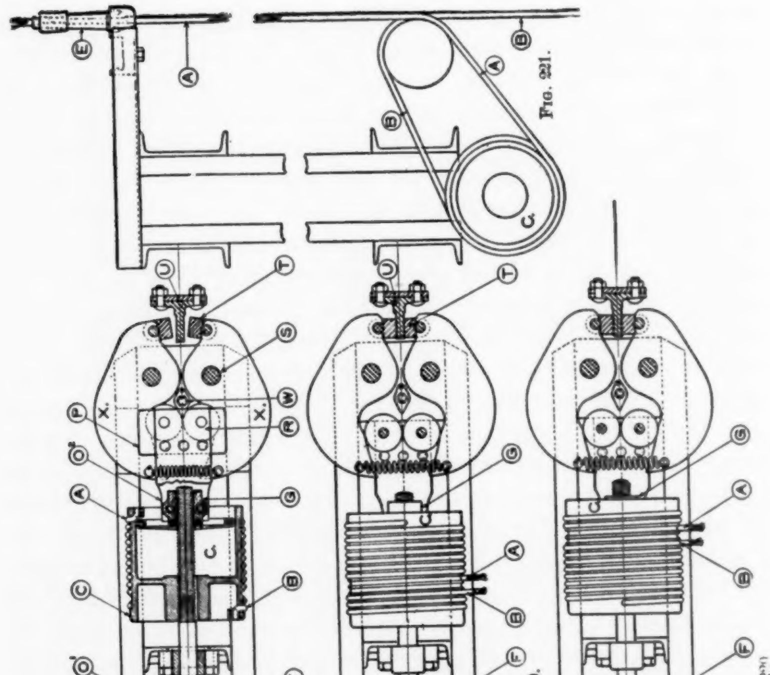

Fig. 218.

Fig. 219.

Fig. 220.

Fig. 221.

safety and comfort to the passengers, under any and all conditions of actual daily practice.

7. Reference to Figs. 218-222, will clearly demonstrate that all of the defects cited in these other two safeties have been

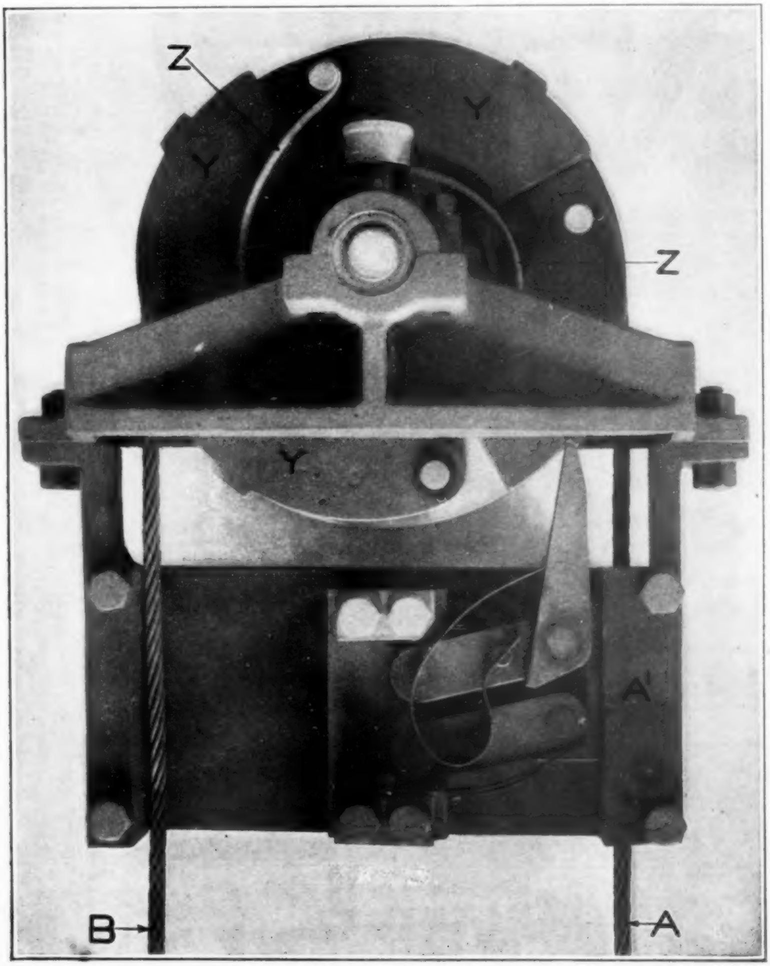

FIG. 222.

entirely overcome, and a radically new principle introduced to properly and safely stop an elevator car by gripping the steel guide rails. Figs. 218-220 show my new type of safety in plan, looking up at the bottom of the elevator where it is carried. Fig.

221 is an elevation showing the governor rope connection. Fig. 222 is a half-tone of the centrifugal governor. That part of the rope *A*, which runs through the grip A^1, leads to the elevator car, passing through a driving grip *E* (Fig. 221); it is then led under an idler

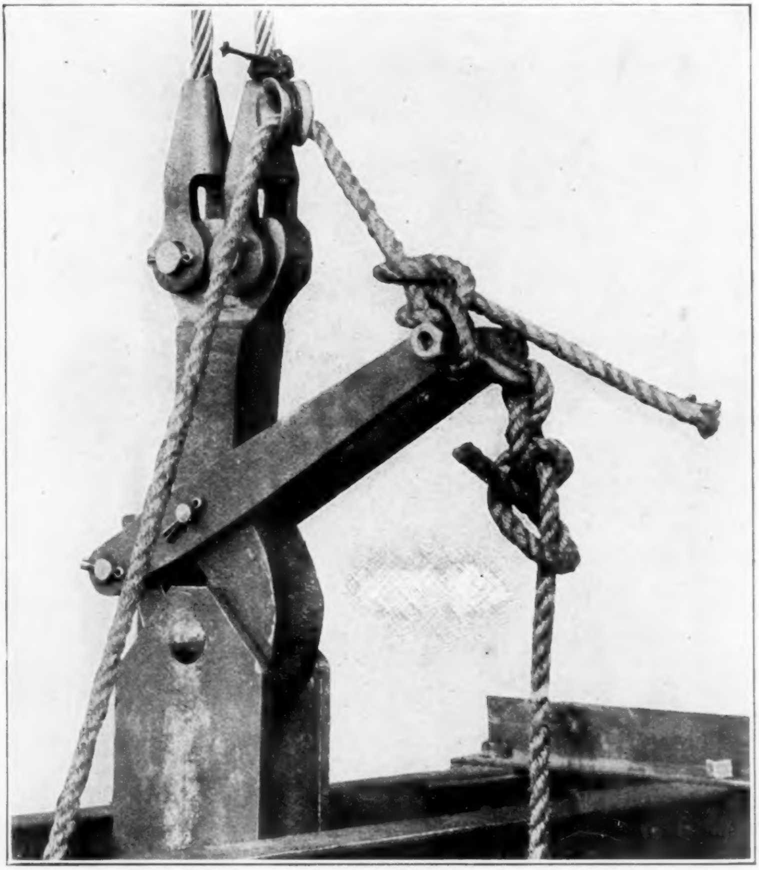

FIG. 223.

on the bottom of the car, wound around the drum *C* and anchored at *A* (Fig. 218). The other part of the rope *B* (Fig. 222) leads down to and around a weighted tension sheave at the bottom of the hoistway, from thence up to and over an idler sheave on the bottom of the car, and from there it is wound around the drum *C* and anchored at *B* (Fig. 218).

The grip, *E* (Fig. 221), is held by a light spring bolt, and when

the car speed down causes the governor to grip and stop the rope, the grip *E* pulls out of its bolt lock. The speed at which the centrifugal governor weights, *Y* (Fig. 222) will fly out and drive the grip down on the rope as shown in Fig. 222, is determined by the tension of the spiral spring *Z*, the same being adjusted by nuts not shown here.

9. The operations in order are viz:

The car in its descent exceeds its normal speed by about 10 per cent., the governor grips the rope, *A*, and stops it.

The car continues its travel, pulling the latch bolt out of the grip *E* (Fig. 221).

The rope *A* revolves the drum *C*.

The drum *C* winds up the rope *B*.

The drum *C* revolves the shaft *D* in the direction to cause it to draw both right and left hand nuts *H* and *G* (Fig. 218) towards each other.

At the first advance of the right hand thread through the nut *H*, the end of the shaft *D* forces the push bar *J* (Fig. 218) to the left and trips the latch *K*.

Latch *K* being tripped allows the spring *M* to extend as shown in Fig. 219, and bring the jaws *T* in contact with the guide rails *U*, within less than two feet travel of the car after the rope *A* is stopped. Further travel of the car compresses the spring *M*, bringing a steadily increasing pressure of the jaws *T* upon the rails *U*, until the car is easily stopped. To release the safety, the drum *C* is further revolved in the same direction by hand pull on the governor rope, until the latch *K* is relatched, as shown in Fig. 220.

10. It should be observed here that push bar *J* clears the path of the screw when the latch *K* is sprung (see Fig. 219), and when returned, as shown in Fig. 220, it bears against the screw by pressure of a light spring which snaps it back into the position, as shown in Fig. 218, when the drum *C* is revolved in the reverse direction by hand pull on the rope *B*, and the nuts *H* and *G* forced apart to their original positions, as shown in Fig. 218. The following essential conditions are, therefore, obtained:

(1) A centrifugal governor of the utmost simplicity and reliability.

(2) The stored energy of a spring to bring the jaws instantly in contact with the rails, but with a pressure and hammer blow too light to jar the passengers or injure any part of the safety.

(3) The steady increase of pressure of the jaws on the guide

rails through any distance of car travel necessary to bring the car to a safe and easy stop. And this is done by the normal closing of a helical spring, and not by the bending of parts which are not springs Fig. 223 shows a trip hook used on one of our shop cars to give free fall tests to elevator safeties.

11. This safety has had several hundred successive free fall tests without a single failure, with no injury whatever to any part, and with no adjustment to any part. These tests were made at all speeds up to 800 feet per minute and 5,000 pounds load. Its load capacity is only a matter of dimensions, and I think this safety will stop on a free fall about three times the load that any other safety of its own weight will stop. I have trusted to the completeness of these drawings to make plain the details with out further description, but I will call attention to the particular advantage of this cam lever action over the wedge or toggles: In the first place, the rolls *R* start with a short leverage on the cam levers *X*, which permits a greater motion of the jaws *T*, with the limited motion of the rolls *R*, and in the second place the enormous pressure on these rolls is taken by their rolling contact on each other, instead of on the pins which carry them.

12. The curve on the ends of the cams gives the equivalent motion of straight line wedges; thus if through imperfect adjustment, or unequal wear, the rolls on one end travel farther than those at the other end of the safety, the pressure of the jaws *T* is alike on both guide rails *U*. Another important feature of this safety is that it is easily released from any part of the hoistway accessible to the governor rope, no means being provided to release it from the car. As nothing but undue car speed should ever operate this safety, it is advisable that the engineer should find out the cause of this undue speed, and see that everything is in proper condition to start before the safety is released.

13. Bending each end (*A* and *B*) of the governor rope around the drum *C* in opposite directions (Fig. 221) puts the drum *C* under positive control of the governor rope. The ease with which this safety can be operated was well demonstrated during the free fall tests; the operations were:

(1) Trip the hook (Fig. 223) and let the car fall.
(2) Lower the hook, make fast and put a tension on the ropes.
(3) Release the safety by the governor rope.
(4) Hoist the car to the tripping place.

Twenty-eight of these free falls were made in 28 minutes.

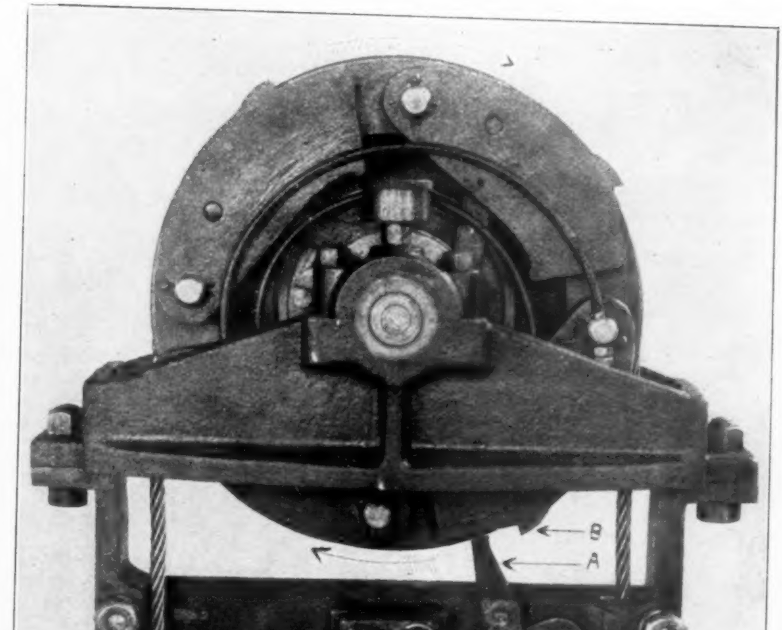

FIG. 224.

ADDED AFTER ADJOURNMENT.

Fig. 224 shows an improved type of the governor shown in Fig. 222.

The improvement consists in attaching a weight to the jaw toggles to pull the jaw down and grip the rope when the centrifugal weights fly out and trip a latch, as shown in Fig. 224. Whereas the jaw in Fig. 222 is driven down against the rope the direct blow of a centrifugal weight and raised clear of the rope by the flat spring shown in Fig. 222.

The defect in the governor (Fig. 222) is that on account of a rebound of the rope, sheave, and weights when the rope is suddenly stopped, the jaw will occasionally be lifted clear of the rope by the spring and thus fail to work.

Believing this to be a radical defect of any type of jaw having spring or other power to automatically release it when the rope is pulled by hand, I have sacrificed any consideration of the convenient release for the sake of absolute safety.

No. 941.*

COLD WORKING SHEET METAL IN DIES.

BY J. D. RIGGS, PITTSBURG, PA.
(Junior Member of the Society.)

1. DURING the last half century a marked progress has been made in the art of working sheet metal. The introduction of more elaborate machinery and tools, and the change from hand-work to die-work, has brought about some very radical changes, both in the design of articles made of sheet metal and in the cost of producing them. The development of this art has led to the use of sheet metal in the construction of a great many articles formerly made of wood or cast-metal. As an example of what we often meet with I may mention that while visiting Cincinnati two years ago, I was shown parts for the body of a violin which had been stamped in dies from an aluminum bronze. These violins were said to be excellent instruments.

2. Dies operated by presses do a large share of the work of manufacturing sheet metal goods, and are useful in cutting out irregular forms cheaply and accurately, but their usefulness does not stop here, for an endless variety of bending, drawing, and forging operations may be done by them, some bending or drawing operation often being combined with the cutting out and performed together with it. One of the most common pieces produced in dies is the end of an ordinary tin can. Referring to Fig. 225, this piece is cut into a round disk and then the annular portion, b, is drawn to the cylindrical form, p.

3. The problem of finding the depth of cup which a disk or "blank" will make may be solved by equating the areas of the cylindrical ring, p, and the annular ring, b.

$$\pi Cp = \pi (C + b) b = \pi Cb + \pi b^2$$

Reducing and allowing for stretch

* Presented at the Boston meeting (May, 1902) of the American Society of Mechaanical Engineers, and foming part of Volume XXIII. of the *Transactions*.

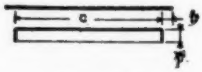

FIG. 225.

$$p = b + \frac{b^2}{C} + s$$

And as the corner is always more or less rounded, we may say

$$p = b + \frac{b^2}{C} + s + \frac{r}{2}$$

where s represents the stretch or elongation of the metal in the edge, p, and varies from 0 to 5 per cent. of p, in tin plate or steel; r represents the radius of the rounded corner. The diameter of the blank is represented by

$$C + 2b$$

4. Fig. 226 shows a typical die as used in single acting presses for forming can ends and similar articles. The right side shows the die closed while the left side shows the relation of parts when open. The hardened steel ring, m, and the steel edge, k, of the punch, i, cut out the disk or blank. As the press continues to descend, the ring, n, clamps the annular part against the face of

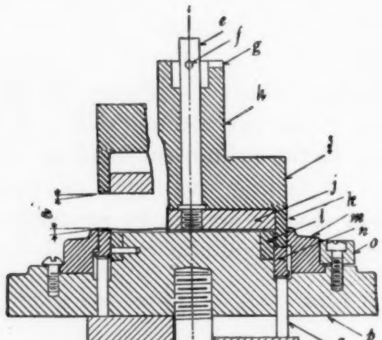

FIG. 226.

the punch, k, and produces a considerable tension in the metal as it is drawn over the central portion, l. As the die opens the ring, n, "strips" the finished piece up from l. Ring, n, is actuated by

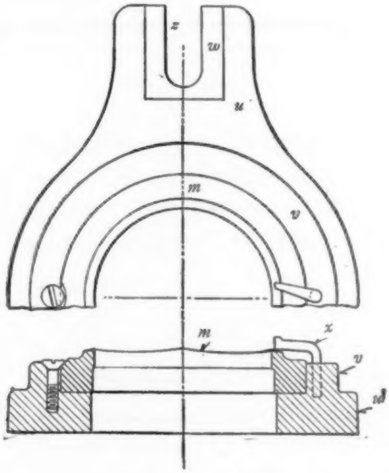

FIG. 227.

a spring through pins, g, and has adjustment by means of a nut on the lower end of the stud bolt, t. Both rubber and steel springs are in use, but either should be amply long. The die (collectively)

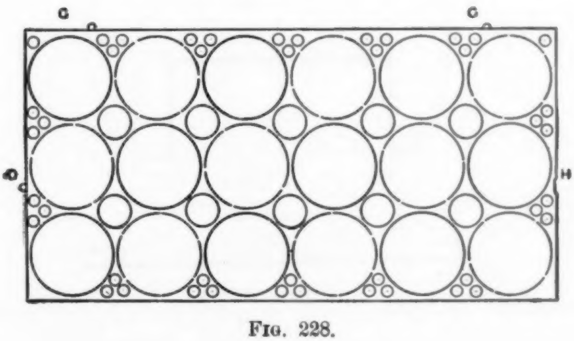

FIG. 228.

consists of the die and the punch. When dies are required for cutting only, the die may be made as shown in Fig. 227.

5. A concern extensively engaged in the manufacture of tin cans has been using for some time dies similar to that shown in

Fig. 226, in "gangs." They leave off the stem, *h*, from the punch and recess the body, *i*, of several into a large plate, and instead of the small plate, *p*, a large one is used with many dies set into it. In this manner gang dies are made to cut the alternate large disks

FIG. 229.

shown in Fig. 228; the sheet is then turned over from right to left, and the remaining large disks cut and formed into can ends. The die rings, *m*, Fig. 226, interfered with cutting all the large disks at one stroke. The remaining sheet is then laid aside, to be after-

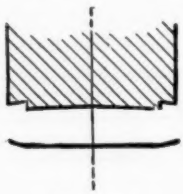

FIG. 230.

ward put into another gang die, which cuts and forms the remaining disks into can caps, shown in Fig. 229, and button blanks, shown in Fig. 230. The die for each group of three small disks, and corresponding to *m*, Fig. 227, is made in one piece, which allows of

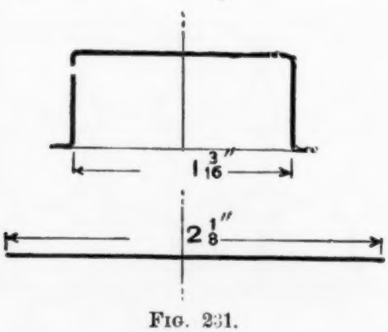

FIG. 231.

cutting and forming the fifty-two pieces at one stroke of the press. Although this gang die formed two distinct articles, it did not mix them together, as the can caps came out on top of the die and slid back in the inclined press, while the button blanks formed or the

peculiar punch shown in Fig. 230, and went through the die. It will be observed that this sheet of tin is not standard size, but is eleven by twenty-two inches, which was a very difficult size to get some years ago. Gauges, *G*, Fig. 228, and notching die, *H*, were so arranged that the irregularity of the sheets would not be reproduced and interfere with using the second set of dies.

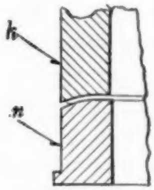

FIG. 232.

6. The depth which may be drawn at one operation is commonly expressed as equal to half the diameter for small cups and one-third or one-fourth for larger vessels. Fig. 231 shows a tin cup formed at once in a die represented by Fig. 226, with the exception shown in Fig. 232. The radial edge of the cup was required, and

FIG. 233.

less than a square corner for the cutting edge of the punch was desirable. This concave face of the punch, *k*, together with a hardened and nicely polished ring, *n*, gave excellent results.

7. Where a depth greater than can be drawn in one operation is required, or a small boss is wanted near the centre of a sheet, it becomes necessary to resort to two or more operations, forming a

larger and shallower piece first, and then reducing this to the desired form.

An interesting example of this class of work was shown in operation at the Pan-American Exposition. The can-top shown in Fig. 235, ready for rolling a thread at *t*, was first cut and formed to the shape shown in Fig. 234, by a die of the type shown in Fig. 226. It then passes through some four other dies and through the forms indicated by dotted lines in Fig. 234, the last one of these

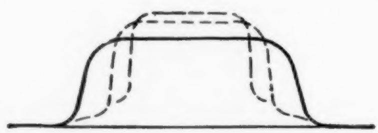

FIG. 234.

dies cutting the hole in the top, trimming and turning the outer edge and shaping it up generally, but not materially reducing the diameter of the boss.

Another example of this reducing is found in one form of bicycle front fork crown, where a boss is formed to which to attach the fork stem.

8. In deep-drawn work the edge becomes irregular, and is often trimmed again before finishing the piece. In Fig. 233 the outer

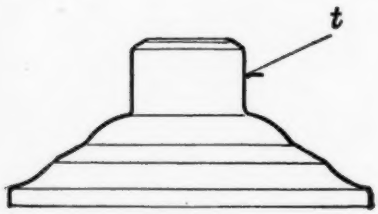

FIG. 235.

line is drawn directly from the piece shown in section in Fig. 234, while the inner line is a circle drawn to illustrate the peculiar irregularity of the edge, showing as is common four high points. I attribute these high and low points to the rolling mill which rolls the sheets.

9. Passing to work done in double-acting presses, Fig. 236, shows a piece formed of tin-plate in a die shown in Fig. 239, where the outer punch, *b*, descends, cuts out the blank, and, dur-

ing its "dwell," clamps the disk against the ring, *g*, while the inner punch descends just far enough to give the required shape. This piece, Fig. 236, is then put into a die, Fig. 240, where the outer

FIG. 236.

punch, *i*, clamps the tapering portion against the die, and the inner punch descends just far enough to produce the piece shown in Fig. 237. This piece is next put through a single acting die, which cuts the holes *o* and *p*, and rounds out the base at *q* some-

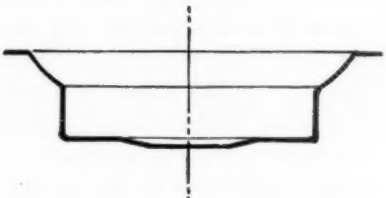

FIG. 237.

what more. The piece is now put into a lathe, Fig. 238, which carries a pair of rotary cutters, *r*, on the back, and a curling roll, *n*, on the front end of the cross slide. After this lathe has trimmed and curled the edge the piece goes into a bath of hot palm oil

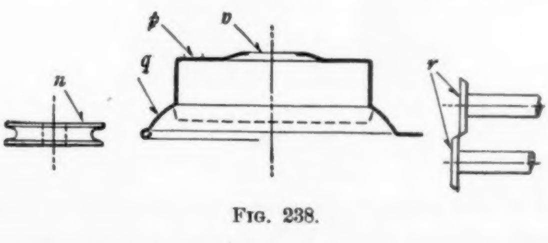

FIG. 238.

to have its coat of tin re-shined, and is then ready to have other pieces attached and form the oil well of a tubular lantern.

10. The trimming cutters, *r*, and the curling roll, *n*, are used in a variety of ways, either together or separately. Three of these

rolls are often put into a body and form a chuck, to be used in a machine similar to a drill press, to curl the edge of pails and round vessels. If the dies shown in Figs. 239 and 240 had been made open bottom, and the inner punches had been adjusted lower, the piece produced would have been a cylindrical cup instead of as shown in Fig. 237.

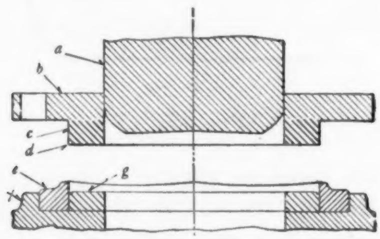

FIG. 239.

11. In drawing and reducing bright steel I have found it possible to draw to 9 inches diameter, anneal and reduce to 6 inches diameter at one operation; but this is rather too much, from 8 to 6 inches is much better. When the side of a cup is to be used as a seamless band without flange, either inside or out, the tool shown in Fig. 241 will be of service in a lathe.

12. It is often necessary to turn a flange around a hole, but

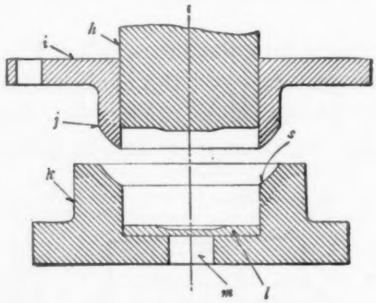

FIG. 240.

this is found a very different problem from turning an outer edge. In turning out a flange $\frac{1}{4}$ inch high around a 2-inch hole in IXX tin so many pieces were spoiled by cracking at the edge that we made new dies and drew the stock in, before cutting the hole. These holes were punched $1\frac{3}{8}$ inch when turning them out to form a $\frac{1}{4}$-inch edge around a 2-inch hole. Another case of this

kind was done by hand tools instead of in a press, and proved entirely successful. In Fig. 242, *R* represents a section of a steel bicycle wheel rim through the hole for the valve tube. The $\frac{3}{8}$-inch

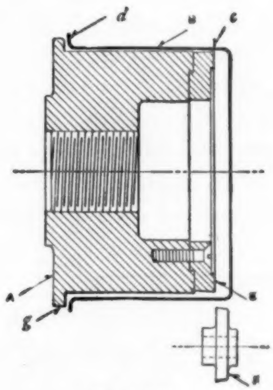

FIG. 241.

valve tube required a $\frac{13}{32}$-inch finished hole. The rim was first drilled to one-third of the finished size. The hand-punch, made to the finished size of the hole with the pilot, *n*, $\frac{1}{32}$ inch larger

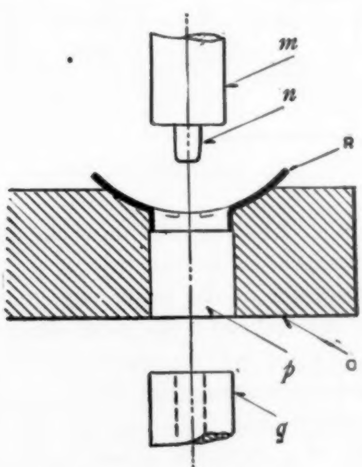

FIG. 242.

than the drilled size, was driven through with six or eight blows of a hand hammer, while the "hold on," *q*, weighing some three pounds, was held up with a light spring. Block, *o*, with $\frac{1}{2}$-inch

hole, p, was held in a bench vise. The material was number sixteen gauge, and reduced to about half this thickness without cracking. The rims were stiffer through this re-enforced hole than elsewhere.

13. Some work with straight sides and sharp angles may be cut out in dies such as shown in Fig. 243, which consists of four hardened steel pieces attached to a cast-iron base. I have not found this to materially reduce the cost of the dies, but the straight sides of both punch and die may be ground true after hardening and in this way improve the work.

The pawl and ratchet may be used in various forms for spacing

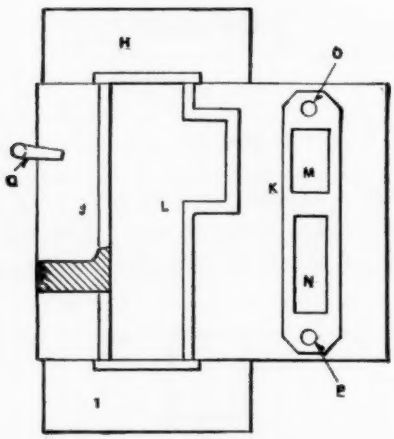

FIG. 243.

holes or notches. Figs. 244 and 245 show the construction of a horn die used to punch holes in the side of a cylinder. In this case a notch in the edge of the work engaged the pin, e; the operator turned to the left until the pawl dropped into a notch and then held to the right while punching a hole. Ratchets are used for notching armature stampings where the ratchet is somewhat smaller in diameter than the work and lies horizontal.

Work on the side of a cylinder is commonly done in a horn press where a horn similar to c, Fig. 244, is attached directly to the back of the press.

14. The particular construction to adopt in making a die will often depend on shop conditions and tools available. The die shown in Fig. 226 contains the hardened ring, m, and the soft tool-

steel ring, *k*. These rings should be made weldless, and *k* may be either welded or brazed to the machine-steel punch body, *i*, while *m* should be ground on the extreme inside and outside and on the bottom. The ring, *n*, should be tool-steel, and may be welded by an expert smith, but if the smith is doubtful, it had better be

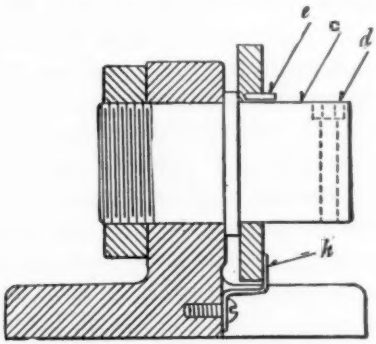

FIG. 244.

forged without welding. When it is important to maintain a standard diameter of work, a hardened ring, *l*, or, in case of lettering or ornaments, a disk is used. In single-acting press dies it is the die centre, *l*, rather than the interior of the punch, *k*, which determines the diameter of the work. It is well to have the interior of the punch a close fit in work, such as can ends,

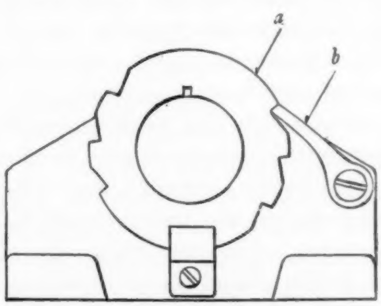

FIG. 245.

where the edge is all drawn in, but in cases where a radial edge is left, such as shown in Fig. 231, the punch may be comparatively loose. In double-acting press dies the inner punch determines the size and often the shape also of the work, while the die may not fit the work all the way but only at the upper corner.

15. In regard to foundry patterns for small die parts I have found it a matter of economy to have on hand 6 or 8 sizes of bottom plate patterns, *u*, Fig. 227, well made and varnished, with core-prints and a core-box to core the slots, *z*, straight sided and to leave a spot, *w*, to finish. To this base pattern pieces are added as needed for individual dies, the same base pattern being used for die Fig. 226 and die Fig. 227, with different additions and in case of Fig. 227 a central core. Die castings made from such patterns need not be machined all over.

16. In dies for double acting presses, which cut the blank as well as form it, a hardened and ground ring, *e*, Fig. 239, is used with a steel ring, *c*, welded to the wrought iron plate, *b*; these do the cutting, and when the corner, *d*, of the ring, *c*, becomes dull it is upset by hammering on the lower face, which must then be turned up again to fit the hardened ring, *e*. The inside plunger, *a*, Fig. 239, may be made of machine steel, for working tin plate or brass; but for working steel it had better be either hardened steel or cast iron. In this particular die a little variation in the diameter of the inner punch, *a*, is of no consequence; if the work had been blanked out first in another die, or cut into disks in the circle shears, then this die might have been made entirely of cast iron, and would consist of only three pieces similar to the die shown in Fig. 240, with perhaps a chilled surface, *g*.

17. The die shown in Fig. 240 was made of cast iron, except the plate, *l*, which was of machine steel. The outer punch, *i*, and the die, *k*, were cast at a car-wheel foundry, and the working faces, *j* and *s*, were chilled very hard. This die worked well on tin plate. Another die, made of cast iron and chilled in the same way, working on black steel which had been annealed after the first operation and was rough, gave much less trouble than previous dies on the same work with hardened steel rings on the faces, although either had to be ground true and polished occasionally.

In drawing deep work, or in cases where the metal is severely worked, it is customary to anneal the work one or more times during the process, but tin plate is ruined by annealing; hence such work is drawn and annealed before plating, or, if some stiffness is required in the finished piece, one drawing operation may be performed after annealing and plating.

18. In cutting and forming bright steel it is customary to use oil as a lubricant and apply it in spots over the sheets before they are cut up into strips. In working tin plate the coating of tin,

together with the thin film of oil left on it from tinning, are ordinarily sufficient lubrication; but in drawing large pieces in a double-acting press a stick of parafine wax may be passed once around near the edge of the blank. In working black steel plate which is to be tinned afterwards, oil is objected to by the tin-house foreman, as making him extra work, and an alkaline solution which will clean in an acid pickle is used, either soda water or a soapy water. One concern buys a soap made from fish oil, puts about a pound of this in a gallon of water and applies with a sponge to each side of the blank.

19. A day's work for a boy or a girl, and a press will depend upon the shape in which the stock comes to the press as well as the speed of the press and the dexterity of the operator. With a die, such as shown in Fig. 226, for cutting and forming ends, 4 inches in diameter or smaller, from tin plate cut into strips, 20 inches long, and wide enough for two rows of ends, an experienced operator will produce from 8,000 to 10,000 pieces in ten hours. With a similar die for making ferules for wood handles out of the scrap thrown into a pile, a boy will probably get 2,000 ferules in ten hours. A press with automatic feed, cutting bicycle chain links, will produce about 90 pieces a minute, working steel in long strips rolled up. The gang die cutting and forming can ends from sheet shown in Fig. 228, cut about 11 sheets per minute, making two strokes to a sheet, while the other gang die described cut about 20 sheets a minute, but from this (per minute estimate) some time is to be deducted for handling stock, etc. A large drawing press on work from 10 to 20 inches diameter, and from 2 to 6 inches deep, will produce from 3,000 to 5,000 pieces in ten hours, but if such work does not "nest" well together it may occupy so much room as to retard the work.

20. The length of time that a die may be used at one sharpening will depend upon conditions and may vary from half a day to two months. The material of the punch and die, the material worked, the angle of the cutting edges, or the complement of *a*, Fig. 226, and the "shear" of the die, are the principal factors in the life of the cutting edge. I have seen dies used for ten weeks on tin plate at one sharpening. Fifty hours is about the average time in an electrical factory for dies cutting number 26 gauge soft steel. Dies cutting bright soft steel for builders' hardware, from $\frac{1}{16}$ to $\frac{1}{8}$ inch thick, with both punch and die hardened, ran from two to four days at one grinding. Dies with square

corners for cutting edges, and no shear on either punch or die, ran about half as long as dies cutting the same pieces from the same stock, with a cutting edge of about 82 degrees, and with shear. The high and low points in the upper edge of *m*, Fig. 227, may be about $\frac{1}{16}$ inch difference in height, and the angle, *a*, Fig. 226, from 5 to 10 degrees.

21. The selection of a suitable press deserves more attention than is sometimes given to it, too small a press being liable to spring and injure the dies, while too large a press is slow and clumsy. Presses for cutting only may generally be much lighter than when used for cutting and forming combined. In a stamping factory the expense may often be greater for dies than for presses, and if a different press is more suitable, it may pay to buy it even though a first stands idle a part of the time.

FIG. 246.

22. The steel best adapted for sheet metal drawing is not readily distinguished from its performance in the regular tensile test, for drawing produces a different form of stress in the metal. We may represent an elementary section of a piece of sheet metal being drawn by Fig. 246, where *p* represents the tensile force due to the thrust of the press and *c c* the compression due to the wedge shape of the elementary piece and its resisting the force *p*. As these elementary pieces abut against each other and are all coming in together, there is comparatively little friction for the force *p* to overcome, and the relative magnitudes of the forces may be represented by the triangle obtained by producing the two sides of the tapering part until they intersect. From this triangle of forces we may conclude that the change of form is due to tension in one direction combined with compression of about twice the magnitude in another direction, while the force in the third direction, or that of its thickness is only nominal, or

just sufficient, to keep the wrinkles from forming. As the stock pulls over the corner, bends, and straightens again, the tensile stress is thrown first to one surface and then to the other, and in this way does more stretching than it otherwise would.

23. Several instances have come to my notice which would indicate that the action of steel under this combined stress of tension in one direction and compression in another, is quite different from that under either stress taken separately.

The two examples mentioned above, where a $1\frac{3}{8}$-inch hole could not be stretched to 2 inches without tearing, under tensile stress alone, and the wheel rim which stretched from $\frac{9}{64}$ to $\frac{13}{32}$ inch under a combined tensile and compressive stress, indicate something more than a variation in stock. In one case we fail to get an elongation of less than fifty per cent., while in the other we get easily an elongation of two hundred per cent.

DISCUSSION.

Mr. Oberlin Smith.—This paper is an interesting one, but my criticism of it would be that it is somewhat fragmentary. This, of course, is because there was not room to put in more details. It certainly deals with so many subjects that it might well be spread out into a book, as I discovered when writing about them some years ago. I have not studied the paper carefully to note any possible errors, but I think I can amplify some of the statements in regard to speeds, and so forth. In one place it speaks of cup-shaped work being $\frac{1}{4}$ to $\frac{1}{2}$ of its diameter in depth, made in a double-action press. The fact is that we can almost always, with ordinary commercial metal, work depths of half the diameter at one draw, and sometimes we can get three-quarters or even a whole diameter. This, however, depends a great deal on the thickness, as well as the toughness of the metal. In thin metals the double-action process has to be used so as to hold the flange from wrinkling, while the punch draws the metal through. But in work where the thickness of the metal gets up to one-tenth or so, of the cup's diameter, double-action punches can be dispensed with, because the metal is too thick to buckle and wrinkle easily, and the downward pressure of the punch will also tend to keep it from wrinkling if the die is of the proper shape. To get the best results, it is necessary to make the die bell-shaped, so that the edge of the blank will be supported in the conical part of the die,

thus keeping a downward pressure and an inward pressure all the time.

In regard to speeds, there is a case mentioned where fruit-can tops which are cut from the sheet, and the edge turned over at right angles and beaded, with a hole cut in the middle and a groove formed around it—five distinct operations at one stroke—had been made at about 10,000 a day. This is a general average, perhaps, of such work, but it often runs higher; and I have known a small colored girl in a Baltimore can factory to make can tops for " one-pound " cans, about three inches in diameter, complete, as above mentioned in a foot press at the rate of 22,000 in 10 hours.

This work can very easily be done at a rate of 12,000, and usually runs along from 10,000 to 15,000.

A speed of 90 a minute is spoken of in regard to a press with automatic feed. This rate can be much exceeded, as far as the mechanical working of the press and the feed-motions are concerned. One limitation is where the metal is thick and more time for flow is needed. With high-carbon steel a very slow ram-speed must often be used, as otherwise the dies will not stand long. With soft iron and steel, and with brass, copper, aluminum, etc., a much higher speed can be obtained, without hurting the dies. Feeding for plain cutting work is often done at a speed of 150 to 250 a minute. In counting the production of a press, instead of taking 600 minutes for 10 hours, we usually take only 500 minutes. This averages about right to allow for the hindrances which actually occur during the day, and is a convenient multiplier. It allows for the operators looking out of the windows, and turning their heads to see what the other men are doing; and if they are attending to their business, it allows also for the bigger item of the dies getting dull and having to be ground or changed for other dies. A very safe and conservative estimate, therefore, is to take the number of strokes per minute and multiply by 500.

There is nothing said in this paper about a very common form of press-work, namely, the coining of money. This is done at speeds all the way from 80 to 140 a minute, the blanks being cut first and fed into the tube of an automatic press, both sides, and the reeded edge being coined at once. I have made small coins like American cents at as high a speed as 200 a minute, where the impression was shallow. There is no difficulty in making the presses run as fast as that, if they are properly constructed with short

strokes and short feeds, but most of the mint presses in use do not possess these improvements. In coining silver dollars of ordinary size (I particularly speak now of some having on them certain elaborate Chinese inscriptions) I found that it was impossible to run as high as 100 a minute, because, no matter how good the dies were, or how high the pressure, the silver alloy would not flow into all the fine lines at speeds over about 80 a minute. Half-dollars of the same design, however, could be coined at about 100, and quarter-dollars at 120.

Another case of fast feeding which may be interesting was in a press that I saw in New Haven, where strips of tin-plate which were less than two feet long were fed by hand at the rate of 200 a minute, small circles about an inch and a half in diameter being cut from them. In general, where the work can drop through the die as in this case, either in plain cutting work or in double-action drawing work, etc., the feeding can be done faster than with so-called " knock-up " work where the cutting and forming are done in single-action dies, and springs drive the work up through the die so that it rests on the top thereof. Of course, as a sheet is passed along, the work has to be shoved off sideways, or in some cases it is driven off automatically. In other cases the press is inclined at an angle of about 40 degrees, so that the metal slides freely backward. Still another method is to blow from the die with a blast of air. Where the work is small, it can be thus blown plenty fast enough to get rid of it. I have seen small strips of thin metal, about half an inch wide, cut and formed into little cup-shaped articles, resembling buttons, entirely by hand-feeding, at 400 a minute. This, however, is a very exceptional case, bringing the production to upwards of 200,000 a day, with single dies—the operator being unusually expert.

Armature plates, of which there is now an enormous production, are often made in one piece at one stroke, the diameters running from three inches to four feet or so. When larger, they are often made in sections, cut separately. Those with notches around the edge are sometimes cut complete, including shaft- and bolt-holes, in dies which cost from $200 to $2,000 for each pair; and they must be made extremely accurate. A great deal of this work, however, especially where electric motors and dynamos are being developed and experimented with, is done by cutting the plain disks first, which can be done very rapidly, and then putting them in a disk-notching press and revolving them automatically, one or

more notches being cut at each stroke. The speed of such a machine runs all the way from 50 to 200 strokes a minute. I have recently done some experimenting to get a higher speed, and have built machines especially for the purpose, making all reciprocating parts as light as possible (tubular, in bicycle fashion and with bronze castings, etc.), putting on a positive lock and an intermittent brake to keep the work from overrunning, together with other improvements making for a higher speed. The machines were for cutting work up to two feet in diameter, and were guaranteed to cut 250 notches a minute. This was above anything that had usually been done, but in starting them up there was no difficulty at all in running at 300. A speed of 360 was then tried and worked just as well as 250. At a subsequent speed of 400 the crank-shaft of the press was too much out of balance to give good results; but with a balanced machine, I believe that work can be done at this speed—that is when the notches are numerous, with a consequent small angular motion in indexing.

I have another item to relate in regard to a machine which I saw recently—not exactly a press, but a special device for cutting and bending wire into staples. It was invented and built by members of this Society, and it worked with remarkable rapidity in making small staples from the coil of wire, the length being about $\frac{5}{8}$ of an inch, and the width $\frac{3}{8}$. The ends were bevelled in different directions, and the wire was slightly flattened. A gentleman who was supposed to know all about wire-working, was invited to the place where this machine was running and asked to give a bid for a very quick working apparatus. He did so, and concluded there might be a speed obtained so that the staples could be cut and flattened, and bevelled and bent at a rate of 150 a minute. So he was taken with his draughtsman to see the actual affair which was already running. It was a simple machine; it would all go within a cubic yard or so, including a direct-connected motor on the main shaft. It was started up and produced the staples at 2,000 a minute, every one perfect, and delivered on to a rod. The gentleman turned to his draughtsman and sadly said, "I think we'll go home."

It may be said, in general, that the science of presses and dies is still largely empirical; it has not advanced as far as ordinary machine-tool work and a great many other lines of mechanical engineering; it is very desirable that our members should study more the general principles involved—especially such as concern

the flow of metal in dies, the tensile stresses at various points thereof, and the pressures necessary for sundry operations of many kinds.

Mr. Jno. T. Hawkins.—I want to call attention to some connection I have recently had with work of the kind mentioned by Mr. Smith, showing the great rapidity with which it can be done, and with a much greater comparative rapidity than anything that has been mentioned so far. I refer to the making of what is called the "crown cork," with which you are probably all quite familiar. This "crown cork" is formed from a disk of tin of about an inch and a half in diameter, punched from sheets, stamped up, thrown out of the dies and off the machine in one operation, and being cupped, and smaller in diameter than the holes, they drop through the tin out of which they were punched as it passes out of the machine. The punches and dies are arranged in these machines, staggered, and so juxtaposed with the feeding and the sheets of tin fed automatically that the inch-and-a-half disks are cut out so as to leave a minimum of waste. Each machine has 14 of the punches and dies staggered in that way, and they are run at 60 strokes per minute. That gives about 840 pieces which are formed per minute, or if running continuously for an hour, about 50,400; in round numbers, for 10 hours' steady running, half a million. With 12 of these machines running at the works the possibilities reach six millions per day. I just thought I would call your attention to this product to show the great rapidity with which the work can be done.

Mr. Oberlin Smith.—I want to "go one better" on the gentleman who spoke of the gang of dies. We have in a cartridge factory a machine cutting and forming at the same time by the double-action process with 16 dies in a gang, certain small brass cups at the rate of 105 strokes a minute, which makes over a million a day. It is self-fed entirely. The whole thing only costs a few hundred dollars.

Mr. Hawkins is the co-inventor of the wonderful 2,000-a-minute machine previously mentioned. I was afraid he was so modest that he would not want me to speak of it. Now that he has mentioned his connection with it, I think it is only right to state that he and Mr. William Painter are its inventors.

Mr. Chas. R. Gabriel.—I think I can beat Mr. Smith's figures on one of his own presses. Some twelve years ago I had to do with the fitting up of a Ferracute press, with gang dies for cartridge

work, to blank and cup 20 pieces at each stroke. The press ran 104 revolutions per minute, making a total of 2,080 cups a minute. These were made from metal in rolls fed automatically, and ran about one hour without stopping.

Mr. Hawkins.—How large are the disks?

Mr. Gabriel.—The disks were from $\frac{1}{2}$ to $\frac{9}{16}$ inch in diameter for 22 and 32 cartridge shells.

Mr. Oberlin Smith.—I am very glad to know it. I had only got up to 16 in a gang.

Mr. Stetson.—I want to relate an incident which took place in Connecticut, where they work things fast. An inventor got up a machine for making pins and interested a capitalist to furnish the money to go on with it. Before going a great ways the capitalist sent down to a certain factory in Connecticut to know how much pins were worth when they were made. The owner of the factory said that the price of pins and wire was the same—it didn't make any difference.

Mr. Hawkins.—I shall not have to revise my figures, but I think I had better revise those of the two last speakers, so far as they are likely to convey erroneous impressions.

We could not expect to form up steam-boiler heads as rapidly as blacking-box covers, nor the latter as rapidly as crown corks. The last speaker named $\frac{3}{8}$ inch as the diameter of the disk from which his cartridge cases were formed. It would not be too much to say, I think, when the extent of movement required in the parts of such machines is considered, that the rapidity with which such cup-shaped pieces could be cut out and formed up by equivalent means, would vary sometimes in inverse proportion to the square of the diameter of the disk of metal required to make them, in which case the gentlemen's figures do not approach the work done on the crown-cork machine referred to; and I still think they are at the head of the procession.

Mr. Oberlin Smith.—In reference to pins being cheaper than the brass they are made of, I want to say that in Connecticut (and I believe it is the only such place in the world) they will sometimes furnish little brass cups and shells of various kinds cheaper than they will the sheet-metal they are cut from. I suppose it is because they can dispose of more of it that way, and the scrap is worth more to them than to us outsiders, who must accept the miserable little price they will pay us for it. Probably the profit on the metal is so great that it doesn't make much difference what shape it's in.

Mr. Gabriel.—There are concerns in Connecticut which sell some lines of brass goods cheaper than the metal can be bought to make the article. I have known in the case of curtain rings which are made from sheet-metal (blanked, cupped, and closed), where they could be bought in thousand-gross lots for less than the price of the metal required to make them. This is in the nature of a paradox to those not posted in the matter, but is possible to manufacturers who make their own metal, as they make a profit on the stock and retain the scrap, which amounts to 50 per cent. in many cases, and is worth more than the cost of making the goods where automatic machinery is employed.

*Mr. John D. Riggs.**—From this discussion it would seem that I have not given the small boys full credit for what they are doing each day. It may be noted, however, that there are many articles made in dies which are not required in such large quantities as are one-pound can-ends or 22-calibre cartridge-shells. A few days' work will often complete one operation on an order, when it becomes necessary to change the boy to another operation or piece before he becomes so expert.

After all, the cost of the finished article does not depend so much on the number turned out in a day, as it does on the quantity of material consumed, if we take the case of the Baltimore girl, who probably receives fifty cents a day for cutting up about twenty dollars' worth of tin-plate. If no special means are employed to utilize a part of the scrap it will represent one-fourth of the material, or about five dollars a day. Mr. Smith complains of receiving a small price for brass scrap, but we are fortunate if we get tin scrap taken away for nothing and do not have the drayage to pay.

In speaking of the press with automatic feed, I should have stated that gang dies were used, and two links produced at each stroke of the press. The press was a standard machine and not designed especially for the production of bicycle chain.

I may mention a case similar to that told by Mr. Stetson, in which a western barb-wire manufacturer had a machine built to make fence staples of No. 9 wire. The parts of this machine except a small "knock-off" had continuous rotary motion, with roll-feed so arranged that it was not necessary to stop the machine at the end of each piece of wire. Different speeds were tried and

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* Author's closure, under the Rules.

the machine finally ran at 420 revolutions per minute, making one staple at a time but two staples at each revolution. All went well and orders for several more machines were about to be placed, when the salesman for the wire mill came along and offered staples at the same price as the wire to make them. This manufacturer bought staples for several years and until he began to draw his own wire, when he also began to manufacture staples.

It seems that wire to sell on the market must be reasonably smooth, round, tough, and to gauge, while no one objects to staples if they are made of wire which is not round, smooth, nor to gauge. Hence scrap could be made into staples; not scrap entirely, but whatever quantity of it there may be about the mill.

No. 942.*

RECENT CONSTRUCTION AT THE ATLANTIC AVENUE STATION OF THE EDISON ELECTRIC ILLUMINATING COMPANY OF BOSTON.

BY I. E. MOULTROP AND R. E. CURTIS, BOSTON.
(Members of the Society.)

1. In view of the selection of Boston as the place of meeting at this time, it was thought that some description of the most recent station construction of the local Edison Electric Illuminating Company might be of interest to the members of the Society, hence this paper, the object of which is not to give such a general description of the company's plant as would be expected in a magazine article, but rather to deal with such special features in connection with the recent extension and partial rearrangement of the principal generating station at Atlantic Avenue as were somewhat peculiar to that station, or otherwise appeared likely to interest engineers. For the more general description, the members are referred to the very full article published in the "Electrical World and Engineer," May 18, 1901.

At the time the original installation at this station was made, direct connected generators were rare, the size of units comparatively small, and vertical engines of the marine type for electric plants unknown in this country. The station of 1891 was, therefore, a pioneer in many of its features, and marked a distinct advance in its engineering in several directions. Nevertheless it was handicapped by certain conditions (notably the shape of the land available and the limitation of size of apparatus procurable) which have been emphasized by recent advances in constructive engineering.

2. It is to be noted that the original plans contemplated one fire room—the cross wall at the chimney being removed—free

* Presented at the Boston Meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

communication between the engine rooms by large open archways, and a switchboard on an open gallery in the engine room. The first installation of machinery included three 650 horse-power vertical triple-expansion engines, each directly coupled to two 200 kilowatt multipolar generators and five Babcock & Wilcox boilers, each of 368 nominal horse-power. Later there were added another engine with dynamos and two additional boilers, all similar to the first, also a 1,200 horse-power vertical cross-compound engine, directly connected to two 400 kilowatt generators, and in 1899 the final installation was made in the old station. This latter consisted principally of two 1,200 horse-power vertical cross-compound engines, similar to No. 5, but each driving one generator only, of double the voltage of the earlier machines, and situated between the high and low pressure sides of the engine, together with four Babcock & Wilcox boilers, each of 418 nominal horse-power, and equipped with chain-grate stokers and with superheaters. Up to that time there had been no departure from the general scheme originally laid down, except the substitution of the two-stage for the three-stage expansion type in case of No. 5 engine. Then, however, several features were introduced which have become standard practice; viz., the use of superheated steam, mechanical stoking, the grouping of boilers in batteries of two instead of in continuous battery, and the single dynamo, operating at from 270 to 300 volts across the outside wires of the three-wire system. All the above engines were provided with individual surface condensers and air pumps, circulating water being furnished from the harbor by a common pumping plant situated in the basement of the boiler house.

3. Hardly had the 1899 installation been put into operation before the growth of the company's business made further extension imperative, and plans were developed for the additions which were constructed in the following year, utilizing the land adjacent to the station and owned by the company, the leases of which were about expiring. During the development of these plans, their scope was frequently enlarged, until finally, instead of the moderate-sized additions at first contemplated, they came to include considerable extensions of station and wharf property; the buildings were carried to their probable final limit, while so much of the apparatus only was then installed as would meet immediate demands, consisting of two 2,400 horse-power vertical cross-compound engines, each driving a single 1,600 kilowatt

generator, four 418 horse-power Babcock & Wilcox boilers with stokers and superheaters and a central condensing plant, together with the usual accessories. A further installation is being made during the current year, consisting of an equal number of units of the same size, and, in general, identical in detail.

4. Before beginning construction, not only was counsel taken of experience with the innovations of 1899 and of the local conditions of situation and current demand, but a careful study was made of other large stations then in operation or under construction, with the result that not only did the new portion of the station develop several new features, but much work was done to improve conditions in the old station and harmonize them with those in the new. In the pages that follow, some of these features will be briefly described and commented upon. It must be borne in mind, however, that the general problem has been constantly hedged about by local conditions largely beyond control of the engineering staff to a much greater extent than in the average station of the size.

Arrangement of Station.

5. In determining the general scheme of the enlarged plant, among the considerations which presented themselves with special emphasis were (a) the desirability of locating the entire switching and regulating plant in a central and convenient position, and (b) the importance of disposing it and the various parts of the steam plant in such a manner that no conceivable accident short of an earthquake or a bombardment could bring about a condition of affairs which would compel the shutting down even temporarily of the entire station. This led to the adoption of the subdivided type of station shown, having two distinct engine rooms, two fire rooms, and a "switchboard" room, communicating conveniently with each other, but capable of instant and complete separation each from the other, so that not only in case of fire or a steam explosion should it be possible to confine the effects to the room in which it originated, but it is made possible for the electrical operator to remain comfortably at his post and to make such manipulations as will protect the generating apparatus involved, and will transfer the load to that portion of the station which can still be kept running.

6. Incidentally it will probably be possible for some time to

carry the entire load with the more modern machinery in the new rooms during the months of light load, releasing entirely at such times the old station with its less economical machinery, and reserving it for busy seasons, when all resources are utilized to their fullest extent.

Again, the change in station architecture required to accommodate and handle the larger units was made without affecting the old station, except that the roof of the old boiler room was raised and coal bunkers installed in continuation of those in the new room.

The means of communication between the engine and switchboard rooms will be touched upon later.

Switchboard Room.

7. The switchboard of the original station was situated in the usual manner on an open gallery in the engine room, and occupied more than one-half of the west wall of the room. Although it was originally intended to place engines the full length of the room on this side, the limited space in front of this board and the danger and discomfort of placing steam pipes and cylinders close in front of it, were strong considerations in determining to locate engines 6 and 7 at the front of the room instead of at the end nearest the boilers.

8. The plan of 1891 contemplated tearing out the screen walls in the large arches back of the switchboard whenever the extension to the station should be built and installing another board, similar to the first, on a gallery at the end of the new room. However, by the time the extension was undertaken, experience had shown that the switchboard installation required to meet the demands on the station would be considerably greater than had been supposed nearly a decade earlier. This, together with the desire to protect the operating centre of the station to the fullest possible degree, and with the feeling that wise policy dictated generous working spaces about the apparatus, led finally to the enclosure of a part of the original engine room for this purpose, and its isolation from the rest of the station by substantial brick walls extending from the basement floor to several feet above the station roof. The original board thus became the nucleus of the larger installation, and its existence in this position naturally led to the selection for the operating room of this central location convenient

to both engine rooms. Communication with the engine room for giving and receiving orders is most satisfactorily established by an installation of Cory signals of the type commonly used on shipboard, there being two sets of instruments in connection with each engine room; one set showing the order, and the other the number of the machine to which it applies. There are also small windows, protected by fire shutters, opening into the engine rooms, for observation and emergency communication, and small fireproof doors for entrance and exit. It would seem, therefore, as though the

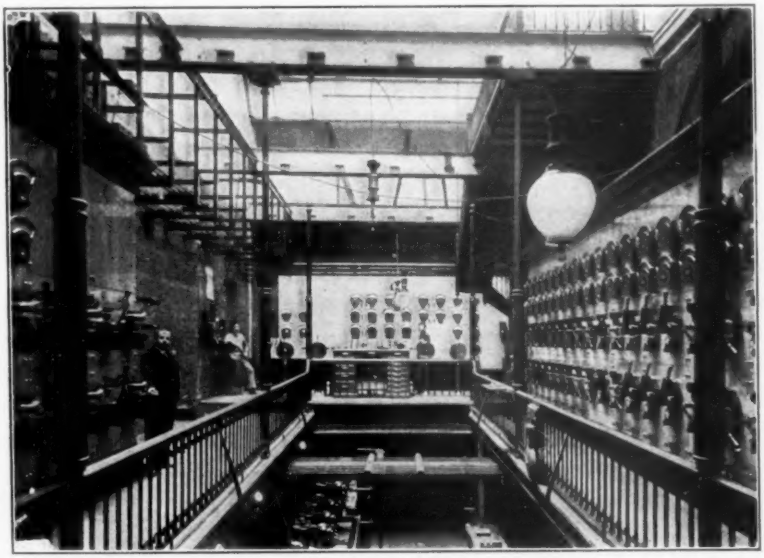

FIG. 247.

apparatus and operators in this room should be practically proof against injury or disturbance from accidents in the station.

9. The structure of the room and its various floors is fireproof. There are at present two floors above the basement, and girders are in place for a third, at the level of the gallery in the new engine room, should it be needed in the future (Fig. 247). All these floors and the treads of the stairways are of slate supported by steel framework. The old switchboard and a similar new board on the opposite side of the room on the same floor are used for distributing the current to the various feeders supplied by this station; also the battery and booster connections are made to this

board. Each board has five sets of bus-bars consisting each of a number of bars of copper laid up together, with spaces between. Short cables connect to the heels of five-point swivelling knife switches, which are of 1,000 and 1,800 amperes capacity, and are thrown by hand. These boards at present contain 44 sets of switches (all of which are in use) with ammeters; they are connected together and to the manufacturing boards below by two sets of tie conductors, consisting of thin copper bars grouped together, with air spaces between, the total sectional area varying to suit the requirements.

10. The manufacturing board is located on the first floor, and to it are connected the various generators and the tie lines to other stations. The term "board" is applicable to this installation only in a conventional way. At present there are two rows each of 20 posts on one side of the room, on which are mounted motor-operated switches of 3,500 and 7,000 amperes capacity. One of these rows is used for positive and the other for negative switches. The busses are similar in type to those on the feeder boards, but of much greater capacity, each consisting of three 8-inch x $\frac{1}{2}$-inch bars, giving a total cross-section per bus of 12 square inches. These switches were built specially for the Edison Electric Illuminating Company, and were the first of their kind. The posts are cast iron of heavy pattern, and each is equipped with five laminated copper switches, each making contact with a lug on one of the five busses, and all with a vertical copper bar carried by the post. Arcing is prevented by a copper spring mounted on the back of the main switch and making independent contact, in connection with magnetic blowouts. The switches are operated by motors mounted on top of the posts through gearing and toggle joints. Interlocking mechanism is also provided, making it impossible to short-circuit on two busses. Switches are controlled by selector switches on the operating table.

11. The field regulating rheostats for the generators are set close to the generators and operated by motors controlled from the operating table. This obviates a long extension of the field circuits to the switchboard room, thus reducing risk of trouble with generators; and in case of accident to the control circuit, hand regulation may be resorted to. The entire system of distant operation and control makes possible a very compact arrangement of switches and regulating apparatus, especially as regards

ground area, brings everything under easy observation, facilitates prompt operation, and greatly reduces the labor of it.

The operating platform occupies one end of the room on the same floor as the feeder boards, and contains the operating table, the signalling apparatus, and the indicating board. The latter is of similar construction and appearance to the feeder boards, and carries ammeters for all generators, boosters, motor-generators, and tie lines, the station and standard voltmeters, galvanometers, and pilot lamps.

12. The operating table stands about breast high, has an inclined marble top, and lies parallel with the indicating board, so that the operator faces both at the same time. It is enclosed by slate sides. On the top of this table are mounted the 6-way control switches operating the switches on the manufacturing board; the switches for operating the distant field controlling rheostats of generators, etc.; the controlling switches for the battery end-cell switches (which are in a separate building nearly 200 feet away), etc.

The feeders and tie lines leaving the switchboards and the main leads from the generators in No. 2 room are of cable, the older feeder cables being carried through the station in iron ducts under the gallery, and the later installations through vitrified ducts in the engine-room floor and the basement of the switchboard room.

The other large conductors within the station, including the booster leads, and the connections to the generators in the old station are of bare copper, each being made up of several thin copper bars separated by air spaces. This is a type of construction which has recently been adopted in several places in the company's different stations, and has proved quite satisfactory. It is not affected by atmospheric conditions which would be quite trying to cables, radiates heat effectively, is less liable to a disabling mechanical injury, can be readily inspected, and is comparatively economical to install. In case of the generator leads, the supports are somewhat different from those used elsewhere. Ætna "barn type" hangers are used, being mounted on a steel framework, which is in turn secured to the floor framing above. As a protection against mechanical injury, each group of coppers is enclosed in a cage of stiff galvanized wire netting, with a sloping roof of sheet steel. The booster leads are supported on slotted slate bars resting on an angle iron structure.

Main Steam Piping.

13. The original steam-piping installation was arranged upon a ring system, the boilers delivering steam into two headers which extended lengthwise of the room, and which were tied together by cross-mains; the latter were extended into and lengthwise of the old engine room, and there again joined by tie connections crossing between the various engine foundations. From these latter the branches to the respective engines were taken. Valves were lavishly distributed over this system, making it theo-

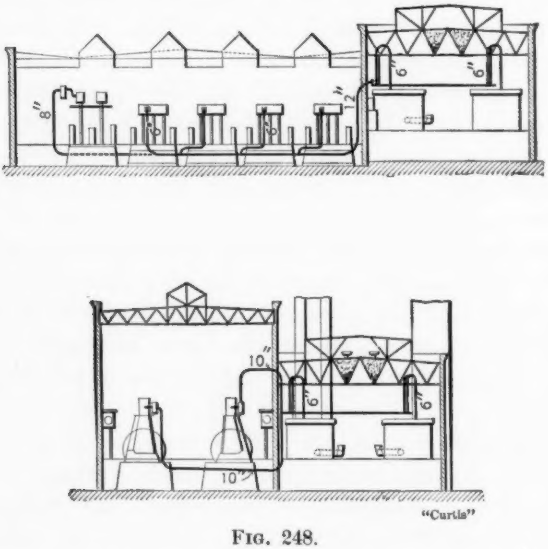

FIG. 248.

retically possible to interchange to almost any desired extent. The construction and arrangement were, it was believed, representative of the best practice prevailing at the time of its installation; but although it had been operated for a number of years successfully and with little trouble, it was considered, in the light of advances in construction and experience, and in view of the use of superheated steam, that it was not the best for the new station, and fresh plans were determined upon for both parts of the station.

14. It was believed that the number of units in the station had reached such a point that the elaborate system of interchange of the old piping was no longer of practical value, and involved

unnecessary complication. It was further held that the ideal arrangement for a large station with similar units would be one in which each engine was connected in the most direct manner possible to a corresponding group of boilers, these various units of piping being interconnected by balance pipes to such an extent only as would equalize pressures, permit taking out individual boilers as needed for cleaning and repair, and make it possible to run any engine or boiler unit in connection with the boiler or engine units next adjoining, in case its own complimentary unit was temporarily entirely out of service. In case the engines are of uniform type and power, and the ground plan such as to allow a symmetrical layout, this ideal should generally be easy to attain, otherwise an approximation only can be made.

The manner in which this was done in this station is outlined in the diagrams (Figs. 248 and 249). It will be seen that the boilers are connected together in groups of about four, each group discharging through a transverse main into one of the series of headers which run lengthwise of the station along the wall separating the engine and boiler rooms. These headers are connected each to those next adjoining by means of 8-inch loops, and from the headers are led the branches to the engines. In case of the larger engines in No. 2 engine room, each branch supplies one engine; while in case of No. 1 engine room the two mains are of slightly larger size, and each supplies a group of smaller engines, the three 1,200 horse-power engines being supplied by one, and the four 650 horse-power engines by the other of these.

15. The auxiliary machinery is supplied from special 6-inch mains, conveniently situated, and fed from the principal mains at various points. All high-pressure lines are drained by "Holly" systems, one being installed for the old station and one for the new.

The distributing mains or "headers" are 12 inches in diameter and limited to about 50 feet in length, consequently expansion is kept down to a moderate figure, which is also reduced by anchoring each header near its centre of length. This practice is also followed in case of the longer branch pipes, the expansion being compelled to take place in a predetermined direction, and such allowances being made in the lengths of individual pieces as will reduce the stresses on the mains when in normal working condition. The former roller bearings have been abandoned for sliding bearings, the friction on these being most efficient in

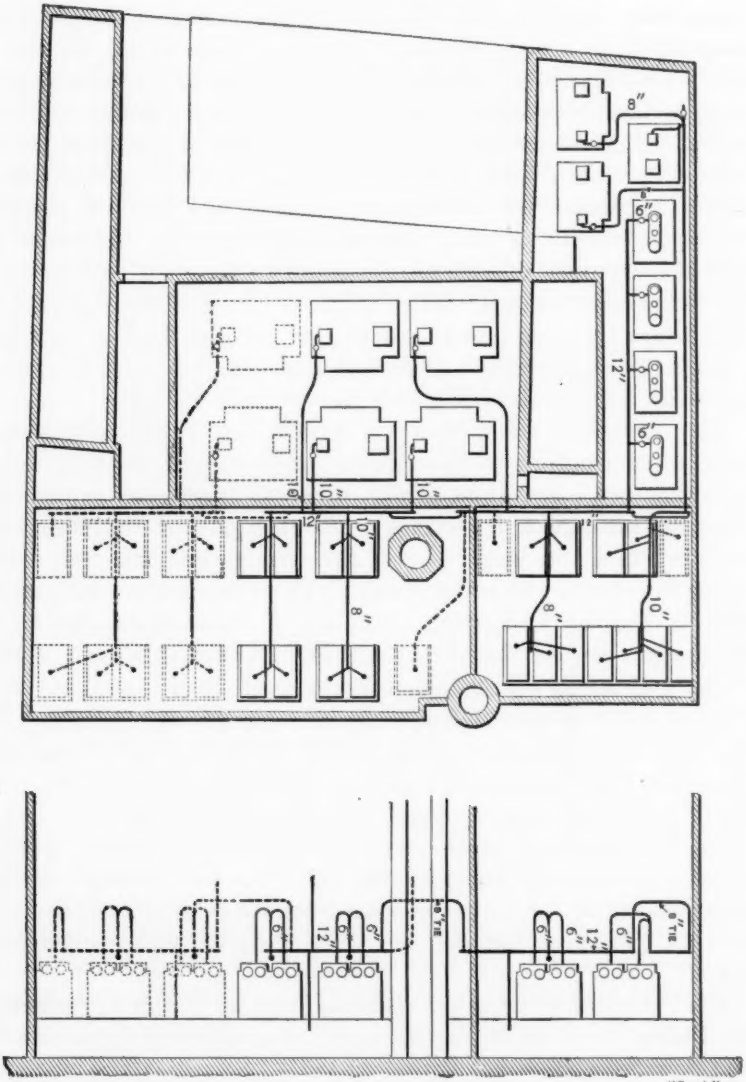

FIG. 249.

eliminating vibration, while not being sufficient to interfere with expansion. In a few cases where the grade of a horizontal pipe was subject to change with change of temperature, compensating hangers on the steelyard principle have been used, and the reaction necessary to counteract vibration obtained by an arrange-

ment of semi-elliptical springs adjusted to take just enough weight to steady the pipe without exerting an excessive force in opposition to the forces of expansion.

16. Screwed flanges were discarded in favor of steel flanges welded on, and the use of copper for high-pressure work definitely abandoned, as it was believed that these steps would not only reduce the number of joints liable to leaks, but would be decidedly in the direction of more uniform, flexible, and trustworthy materials. The former policy of using air-furnace gun iron for fittings has been continued, great care having been taken to choose such forms and dimensions at the junctions of flanges and branches with the bodies of the castings as will tend to soundness of casting and easy flow of steam. The company's specifications call for an iron of from 28,000 to 32,000 pounds tensile strength, and a very tough, compact, and reliable material is obtained. Joints are tongued and grooved, made up with thin corrugated copper gaskets, and heavily bolted.

A special feature of the piping is the installation, in connection with all valves controlling the branches from the boilers or other mains supplying steam to the headers, of auxiliary valve stems leading off through solid brick walls to points from which they can be operated regardless of conditions at the valve. This makes it possible in case of a disabled steam line to positively cut off the break in the quickest order. Stop-check valves in each boiler branch also give additional protection to the fire room. It will be noted that the change of pipe scheme made it possible to reduce the pipe sizes over those of the former system, 12-inch being the largest size now used against 15-inch in the old lines. The branches from the boilers were reduced from 8-inch to 6-inch, and other lines kept to moderate sizes. Inasmuch as heat units at the engine were what was sought, the reduction in radiation was held to be of more importance than a slight drop in pressure, although drop and velocity were kept within reasonable limits. Large receiver separators at the engines, with enlarged connections to the cylinders equalize the fluctuations in branch pipes due to cut-off.

Central Condensing System.

17. A central condensing system (Fig. 250) for the new portion of the station was determined upon in the belief that it offered the best opportunity of developing the space in the main station

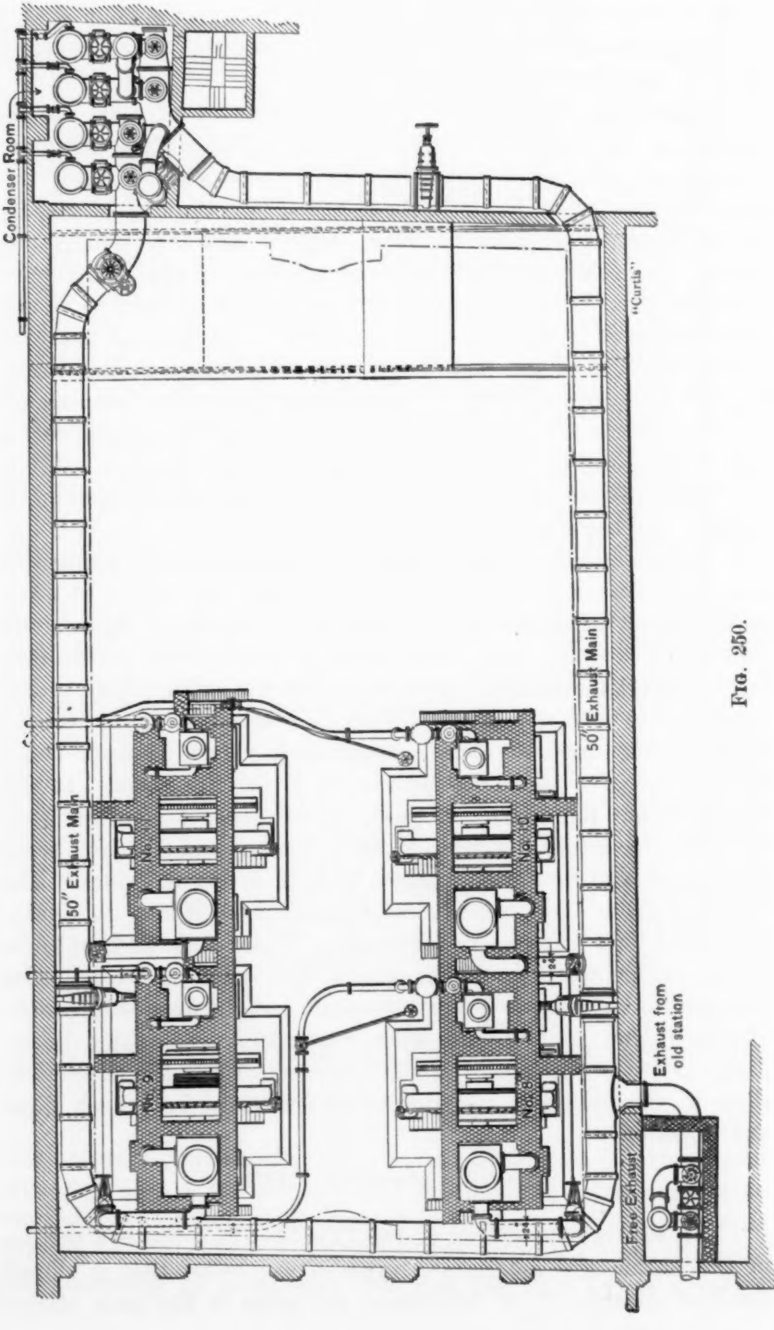
Condenser Room
"Curtis"
50" Exhaust Main
50" Exhaust Main
No. 9
No. 10
No. 8
Exhaust from old station
Free Exhaust

FIG. 250.

for generating purposes, and would give the most compact and conveniently operated condensing plant with a satisfactory economy. Advantage was taken of an otherwise unoccupied area included between the engine house, boiler house, and the adjoining buildings for the installation of the condensing machinery, so that no floor space is taken up by it in the station proper. The complete plant will include four air pumps with jet condensers and feed-water heaters in the condenser room, and a riveted steel exhaust main extending from the condenser room in either direction and entirely around the new engine room. The first installation, made in 1900, consisted of one-half the condensing machinery (two complete units) and that part of the pipe extending around the easterly and northerly sides of the room and to a point beyond No. 8 engine. The remainder of the condensing machinery and of the main and a connection to engines 6 and 7 in the old engine room are to be installed during the current year. Therefore, in describing it, the entire system will be considered as completed.

18. Each condensing unit is of 5,000 horse-power nominal capacity, and consists of a vertical twin-beam Blake air pump with 16-inch steam cylinders, 44-inch water cylinders, and 24-inch stroke, with a jet condenser attached. Circulating water is taken from the harbor through a sluice 7 feet wide by 11½ feet high, with its floor 8 feet below mean low-water line, and is returned through a 48-inch cast-iron pipe. Above each condenser, and connected to it by 40-inch cast-iron piping, is a vertical Goubert feed-water heater 58 inches in diameter of shell, 17½ feet high, and containing 1,333 square feet of heating surface. The exhaust steam reaches the heater from the engines by means of the main above mentioned, which is 50 inches in diameter, each leg being connected to the heaters of two condensing units, and the two legs interconnected by a 40-inch valve.

Chapman gate valves are placed in the main in such positions as to divide it into three sections, to each of which will be ultimately connected the exhaust from two of the six engines forming the full equipment of this room. Each section is provided with two 24-inch Gallison relief valves discharging through galvanized iron risers, respectively 30 and 36 inches diameter, which terminate above the roof in Sturtevant exhaust heads.

19. The portion of the main within the condenser room is of cast iron with suitable outlets for connection to heaters and re-

lief valves, while the principal portion of the main is a riveted steel pipe. This latter is, perhaps, the most interesting feature of the condensing system, as it is only by the most careful design and workmanship that a riveted pipe can be depended on for such service. So far as known, there was no precedent applicable to the case, but after consulting with parties experienced in boiler construction, it was concluded that a satisfactory pipe could be built, and the contract was executed by a local concern.

The main is made up of $\frac{3}{8}$-inch flange steel plates, all joints being butted with outside straps, and rivets being countersunk and driven flush on the inside (Fig. 251). Roundabout butt straps are 9 inches by $\frac{3}{8}$ inch, and longitudinal straps 5 inches by $\frac{1}{2}$ inch. Longitudinal seams are single riveted, and roundabout seams double riveted, all rivets being $\frac{3}{4}$ inch diameter in drilled holes, and pitched about $2\frac{1}{4}$ inches centre to centre. All seams were caulked inside and outside, and great care was taken in cleaning, planing, rolling, and fitting plates to secure perfect tightness.

Each course is made of one plate, the longitudinal seams being about 20 degrees either side of the vertical centre line at the top of the plate. Courses generally run from $7\frac{1}{2}$ to 8 feet in width, although a few are as wide as 9 feet 2 inches. Bends were also riveted up, the right angle (approximately) bends being made in four courses, each with a radius at the centre of the pipe of about 9 feet. Cast-iron companion flanges for the valves, manhole frames for each section, and nozzles for the branch exhaust pipes were carefully fitted and riveted to the pipe.

20. The greater part of the pipe proper is supported by cast-iron saddles riveted to the under side of the shell, and resting upon cast-iron bearing plates, which are secured in turn to the engine-room gallery framework. These supports are placed about 16 feet apart, and each provides about $1\frac{1}{2}$ square feet of bearing surface. At the valves heavy cast-iron saddles are provided, fitted under the flanges and resting upon " I " beams. The main is secured in place at the condenser-room ends, and at the opposite end of the room it is so confined that movement lengthwise must take place in either direction from the centre, otherwise it is not confined, except by the friction on supporting plates. The actual expansion in a length of about 135 feet was $1\frac{1}{4}$ inches with one engine running non-condensing, which reduced to $\frac{7}{8}$ inch when running condensing.

21. Each condensing unit comfortably cares for two engines.

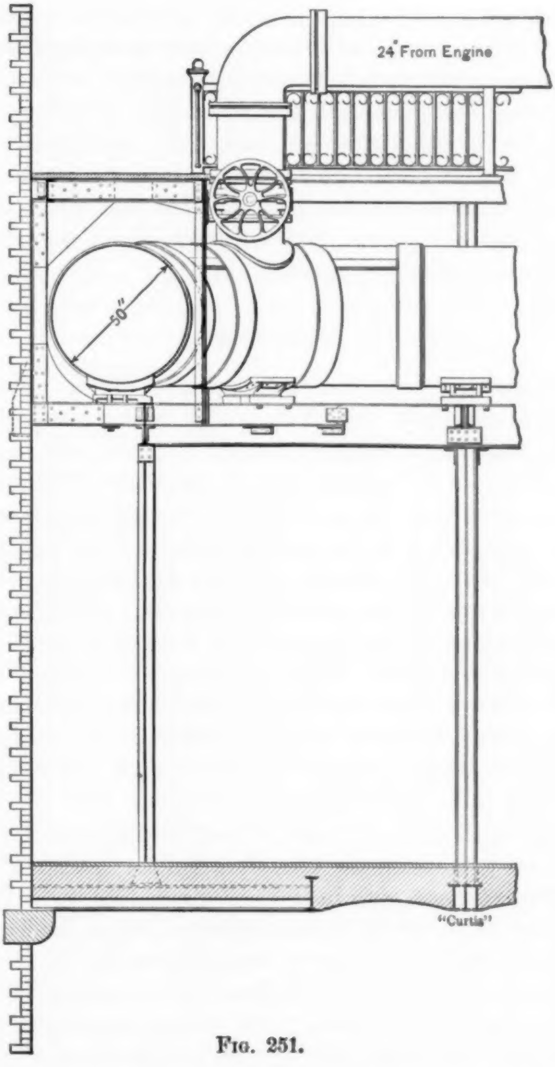

FIG. 251.

The loss of vacuum between pump and engine is small, and if allowance were made for friction in the heater and in the branches from the individual engines, the drop in the main would undoubtedly be negligible. A somewhat less vacuum was to have been expected with a condensing system like this than from condensers close to the engines, especially with the central system loaded only to a fraction of its capacity; but in practice this loss

has not appeared to be serious, and it is believed to be outweighed by the expense, complication, and inconvenience of the pipes and connections which would otherwise have been required in the engine room, not to mention the advantage of releasing valuable space there for other uses by placing the condensing plant in an otherwise useless area. So far the main has remained bare without being troublesome, but it is possible that when the full projected engine equipment shall be installed, it may be necessary to apply non-conducting covering.

Superheating.

22. Beginning with the installation of 1899, all new boilers have been equipped with Babcock & Wilcox superheaters, designed to superheat from 100 to 125 degrees, and applied in the usual manner in the central pass of the boiler. There are therefore at present 4 of the 11 boilers in the old station so equipped, together with the 4 in the new station, and the boilers to be installed this year will also be provided with superheaters.

It is unfortunate that conditions are such as to prevent the exact determination of the gain realized from their use.

Comparative results, based on occasional tests of the various engines, indicate an increase of economy varying according to the distance from the boilers and the quality of the steam furnished. As there are always several boilers in service in the old station, which have no superheaters, No. 9 engine (the one nearest the new chimney) is the only one of those installed so far which can be assumed to have at all times the fullest benefit of the superheat. The other engine in the new room (No. 8) is liable to get some of its supply from non-superheater boilers, and has the relative disadvantage of a longer branch from the main. With the usual service combination of boilers, the superheat at the throttle of No. 8 engine ranges from 70 to 80 degrees Fahrenheit, and at the throttle of No. 9 engine from 80 to 100 degrees; while at the throttle of the engines at the street end of the old engine room, where a large proportion of the steam is drawn from non-superheater boilers, and traverses approximately 180 feet of pipe after leaving the header in the boiler room, there is still a little superheat left, say, 5 to 10 degrees ordinarily, which may occasionally be increased to about 25 degrees under specially favorable conditions.

23. Probably the best argument for superheat under these conditions is the fact that a considerable and progressive improvement in the economy as gauged by coal used per kilowatt delivered to the switchboard has been obtained as a result of recent installations, a considerable part of which cannot be assigned to any other cause.

However, the following results of acceptance tests on engines No. 8 and No. 9 may be of some interest. They were taken in case of both engines at approximately normal full load, and under practically identical conditions except length of steam supply pipe. Tests A and B were taken with jackets and reheaters in service, and tests C and D without.

Test	*A*	*B*	*C*	*D*
Engine under test	No. 8	No. 9	No. 8	No. 9
Average indicated horse-power	2,267.0	2,201.6	2,239.8	2,215.1
Jacket water per indicated horse-power hour	0.825	0.78		
Total water per indicated horse-power hour (including above). Actual conditions	12.72	11.57	12.98	11.88
Total water per indicated horse-power hour corrected to dry steam at 160 lbs. initial and 26 incheseffective vacuum	12.51	11.64	12.61	12.00
Superheat at throttle, degree F.	80.2	98.4	78.5	98.4

24. There was a noticeable improvement in the quality of steam during expansion as compared with earlier engines, but moisture is not yet entirely absent in either cylinder, and there must be a considerable increase in the amount of superheat at the throttle before the reheater between cylinders can be omitted and saturated steam can be delivered to the condenser.

It is, perhaps, worthy of note that all the compound engines at the station are McIntosh and Seymour engines with their standard valve gear including sliding gridiron valves which have so far proven perfectly adapted to the service.

The superheaters have given no trouble whatever up to the time of writing, nor has there been any trouble with piping or valves on account of the quality of the steam.

Coal Handling Plant.

25. The main elements of this plant are:

(1) A steel coal pocket running the full length of the water front and parallel to the pier-head, and a wooden shed and an open storage space in the rear.

(2) Three unloading towers traversing the top of the steel pocket, the two older and smaller being built of wood and operated by steam, and the new and larger being constructed of steel and operated by electricity.

(3) Bunkers of triangular cross-section included within and supported by the boiler-room roof trusses and extending the full length of the room, and

(4) A system of elevated narrow-gauge cable railway traversing all the above.

The principal interest centres in the electrically-operated tower, some idea of the situation and general arrangement of which can be gained from Fig. 252. It will be observed that the booms of this tower extend out on both land and water sides, enabling it to deliver coal from the vessel into the pocket or the open storage space behind it, or to deliver from either the vessel or the storage area into the cars of the cable railway. The floor of the tower is about 24 feet by 33 feet over all, framed up of 15-inch beams and channels, and carried upon eight 33-inch wheels. The tower structure rises vertically with uniform outside dimensions of about $21\frac{1}{4}$ feet by 30 feet to a level 30 feet above the floor. Above this level the form is that of a pyramid 55 feet high. The various grades reckoned from the top of the wharf are approximately as follows: To top of rails, 43 feet; to bottom of boom, 76 feet; to peak of tower, 131 feet.

The boom on the land side is fixed in position and extends out 72 feet from the centre of the tower, while the boom on the water side slides, telescoping the fixed boom, and can be run out to a point 62 feet from the centre of the tower. The bucket can traverse the entire length of both booms.

26. The machinery is placed on the main floor of the tower. On one side are the hoisting drums driven by two 100 horse-power multipolar motors, one on each end of the shaft and wired to be run in series or in parallel. The resistances for these motors are cut in or out by a system of solenoid switches operated by a master controller on the operating floor. On the opposite side of the tower is a similar but smaller set consisting of two 40 horse-power motors and the drums operating the trolley. The controller for these motors is of the usual type. On an extension of the shaft of this set are the drums for running the boom in and out, and winch heads for traversing the tower along the top of the pocket. The operators are on a floor over the machinery, one being on

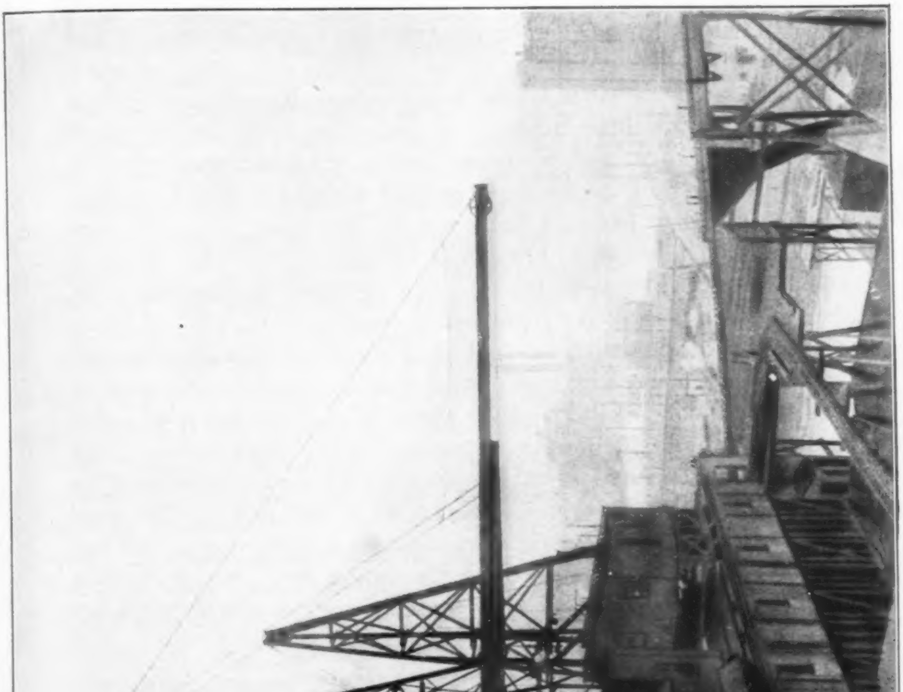

FIG. 253.

each side of the boom and operating respectively the hoist and the trolley. The current supply is taken by special collector shoes from a flat copper bar, supported from the side of the pocket and kept taut by weights.

The tower is provided with a 2-ton clam-shell bucket, which can be raised about three times a minute. The cable railway is of $21\frac{1}{2}$ inches gauge, and is equipped with self-dumping cars of $2\frac{1}{2}$ tons capacity, each mounted on two four-wheeled trucks. The cables are electrically driven. This part of the plant operates very smoothly, and does in a very simple manner what, under the same conditions, would undoubtedly have required a complex plant had another form of conveyor been adopted.

27. As will be noted, the coal handling system has been worked out in a much more comprehensive manner than the demands of the station alone would seem to warrant, and this has been made possible by joining forces with one of the principal coal retailing concerns in the city, which also supplies from the same wharf a large local trade, using the same grade of fuel. Also, the proximity of the large storage sheds and areas on the wharf, with the facilities for drawing upon them for station use, made it possible to reduce the station bunkers to their very moderate capacity (about a day's supply), greatly simplifying the construction and reducing the cost of the boiler-house roof.

Miscellaneous.

28. The handling of ashes at this station has been reduced to a very simple system. They drop from the grates directly into chutes, from which they are drawn off from time to time and teamed way. This manner of disposing of them, never very expensive, may at times, when there is a demand for them for filling, even prove slightly profitable. The standard type of chute for the old station has been a steel-plate hopper lined with firebrick. For the new boiler-room a construction was devised which afforded a capacity equal to one day's production of ashes. It is a masonry structure, supported by a steel framework from the main floor framing, and consists of brick-retaining walls and a sloping bottom of cinder concrete, all lined with firebrick. A rotating gate is provided, specially designed, to economize height. As the ashes fall from the stoker close to the bridge wall, the latter is supported by a set of three 10-inch cast-iron I beams, and

the chute extended back under and somewhat beyond it so as to obtain the maximum capacity.

29. While installing the considerable number of large valves (24 to 48 inch) required in the newer part of the station, it was felt strongly that some means of operating such valves more conveniently, and much more expeditiously than by hand, was a prime necessity. Particularly and from obvious reasons this was felt to be true in regard to the valves controlling the exhausts from the individual engines. Every possible motive power was investigated, but no type could be found satisfactorily meeting the requirements in season for the original installation, and they were put in of the ordinary geared hand types. This matter has, however, been vigorously followed up and two 24-inch valves, equipped with different types of electric operating mechanism controlled from distant points, have been recently built and will be thoroughly tested in service. Enough has already been learned to make it practically certain that all valves 24-inch and over will shortly be motor driven.

30. In closing it may not be amiss to mention the generator of No. 9 unit. In this machine there is provided, besides the ordinary commutator, a set of collector rings connected to the same armature winding. Thus it can be used to deliver direct current in the usual manner from the commutator, to deliver low tension six phase alternating current from the collector rings, or to deliver both simultaneously in any desired proportions. This type of machine, though not peculiar to this station, is not common. Obviously in connection with static transformers it would enable high potential alternating current to be transmitted from a low potential direct current station, without the use of rotary converters at the generating station.

Hereby is strikingly illustrated the uncertainty of some of the factors with which engineers have to deal, for at the time this generator was ordered, the Edison Company shared the local field with a strong competitor, which furnished the arc lighting for the city and served a considerable business distributed over a wide territory, from a modern alternating current station in South Boston. On the other hand, the Edison business was to a great extent concentrated in a compact district about the business centre and naturally its plans proceeded on the basis of a low tension station with auxiliary high tension distribution of the comparatively small output required for the outlying sub-stations in the residence

sections. To this plan the double current generator was well suited, and had those conditions continued for some years, as seemed then probable, it would undoubtedly have prevailed in later installations.

31. However, a rapid succession of events has culminated in the union of the two companies and the natural outcome in operation will be to distribute to all outlying stations from the alternating station at South Boston, and to furnish direct current for the combined business of both former companies in the down-town district from the Atlantic Avenue station, so that, for the remainder of the plant at this station, the direct current machine will undoubtedly be the standard instead of the double current machine, as originally anticipated.

DISCUSSION.

Mr. F. V. Henshaw.—The paper of Messrs. Moultrop and Curtis is interesting as illustrating modern engineering practice in central station construction. It is but a truism to say that our civilization is founded upon the generation and utilization of power; and the enormous increase in the size of central power generating stations in the last few years is significant. There are at present four new power stations in the city of New York, the rated capacity of which range from 44,000 to 83,000 horse-power with a maximum capacity of about 50 per cent. higher. There is also the enormous station to be built for the operation of the Rapid Transit Subway, which is to have a capacity of some 100,000 horse-power. Every effort of the best engineering talent has been devoted to designing central power stations for the production of power at the least cost, and with the large financial interests involved, actuated by the modern progressive business policy, the value of improvement is rarely a question of first cost, but rather of its yielding a profitable return.

Considering these facts, it has seemed strange to me that one item in the economies of central stations has been given such scant attention not only in the paper before us, but generally in articles dealing with central station economies.

I refer to the cost of water for stations located in large cities. In the elaborate papers of the late Charles E. Emery on the cost of steam power generated in large quantities, there is no mention of this item, nor do I find anything but casual and brief

allusions to it in a number of articles on the like subject. I have, therefore, thought it would be interesting to suggest this question for discussion, in the hope of bringing out the facts from those who know.

It will be observed that in the station described in the paper before us, the original steam plant was furnished with surface condensers, whereas the new central condensers are jet, which is also the type of condenser used very generally in the large central stations in seaboard cities. Even those who use surface condensers have apparently installed them with the idea of some day utilizing the condensed steam as feed-water, but are not doing so to any great extent at present.

In Mr. Haupt's book on street railways he gives the cost of water and oil in the central station at 15 per cent. of the cost of the coal. If cost of water from the city supply is taken at $1.00 per thousand cubic feet, coal at $2.50 per ton, and we assume an evaporation of eight pounds of water per pound of coal, it will be found that the cost of the water is a little over 10 per cent. of the cost of the coal. For a station developing 10,000 horse-power continuously for 365 days in the year, this would be equivalent to over $18,000 per year for the water if the latter is thrown away.

Now, why in these days of fine economies is this waste permitted? The answer I have received is the fear of oil in the boilers, and that is the only conceivable reason. If an apparatus could be constructed to separate this oil and save even one-half of the water, we would have on the above 10,000 horse-power output a saving of $9,000 per annum, and could afford to spend say $100,000 for our oil-separator, and allow a very liberal margin for interest and depreciation. In the great station to be erected for the Rapid Transit Railway in New York, the water bill will not be less than $40,000 per annum; and I have been told that it is estimated at nearly double this, and that the Rapid Transit people have been unable so far to obtain a satisfactory guarantee that they could use their condensed water over again without risk to their million-dollar boiler plant. There are any number of small plants throughout the country which are saving their exhaust steam and apparently having no trouble. I believe the Imperial Light and Power Company of St. Louis, with surface condensers and cooling tower system, use their water very economically. I will not mention marine practice, as that is for many reasons different from

stationary practice, but I would call attention to Mr. C. T. Porter's remarks in a discussion of Professor Thurston's paper before the American Society of Mechanical Engineers in December, 1899, in which he said that in the steam plant of the future there must be no oil in the boilers, which result might be accomplished by graphite cylinder lubrication. To blow solid matter of any kind into an engine cylinder would seem decidedly risky, but is there not room for improvement in the direction of reducing the amount of cylinder-oil used?—and why cannot a device or, if necessary, a combination of devices, as for example the ordinary receiver separator, centrifugal separator and feed-water filter placed in series, be constructed at a cost that will make it a profitable investment in the value of water saved? In addition to the saving in money, the utilization of the exhaust steam for feed water will go far toward solving the hard-water problem where such exists, and it is also of importance to consider that in large cities the water supply is more or less limited, and it is a question as to whether such cities can always undertake to furnish the enormous quantity of water required by large power stations which throw away their condensed water.

Mr. W. H. Morse.—Mr. Chairman, I should like to ask Mr. Curtis one question in regard to his superheaters. I see they have been installed about two years. I judge they are of the U type furnished with the Babcock & Wilcox boiler. He states that there has been no difficulty with them. Have they been examined for pitting in any way during these two years; has any deterioration been noticed?

Mr. Curtis.—In answer to that question I would say that the superheaters are under constant inspection, and, so far as I know, no defect whatever has developed.

*Mr. Moultrop.**—In reply to Mr. F. V. Henshaw's discussion of the paper, I would say that in building the new portion of the station under consideration, we installed jet condensers for the reasons that it was general practice so to do; that the city water we get in Boston is very good and very cheap; that it simplifies the construction and operation of a big station to waste the condensed steam, and that, owing to the cost and quality of the city water, the probable net saving in re-using the condensed steam would be so small as to make the installation and operation of any system of water-purifying apparatus an unwarranted expense.

* **Author's closure, under the Rules.**

We have had some experience in removing cylinder oil from the condensed steam. In the older part of the Atlantic Avenue Station, where the engines are all fitted with surface condensers, we ran the station for some number of months at a time in this way, but at the end we felt, as stated above, that the saving was too small to pay for the trouble of operating filters, and the risk that some one might be careless.

In a small station where the apparatus installed is only a few thousand horse-power, it is possible, and it is probably good engineering, to go into all these refinements which promise to better the economy of the station; but when you reach a station of 20,000 horse-power and upward, we believe the engineers in charge should have the simplest possible kind of a station to operate, and a station of this size, built so that there is no chance for oil reaching the boilers, will be better operated by removing this cause for worry on the part of the operating engineers.

No. 943.*

A ROLLER EXTENSOMETER.†

BY GUS. C. HENNING, NEW YORK.
(Member of the Society.)

1. AMONG the earliest types of apparatus for measuring elastic changes of length of material under test, we find the multiplying roller, consisting of a bar resting at one end upon the test piece and at the other separated from it by a roller which carries a long pointer mounted on a diameter of the end face of the roller, its outer end sweeping in either direction over a graduated arc carried by the free end of the bar first mentioned, as the test piece changes its length. Such apparatus ‡ was much used by Bauschinger in his famous investigations. Many other similar pieces of apparatus § were constructed from time to time, and are now in use for various purposes, with more, or generally less success, because of inherent errors, complication of design, or difficulty in use.

In this new type of the instrument there are two frames; one carrying the distance pieces or gauge rods, the other the working or reading parts, which, while placed symmetrically around the test piece, also mark off the gauge length on which observations are to be made, and can be used in vertical or horizontal position with equal facility and reliability.

2. The frames are similar to those used in the mirror ‖ and recording apparatus ¶ previously described in the *Transactions*, in

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* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For further references on this subject see *Transactions* as follows:

Vol. xviii., p. 823: "A Pocket Recorder for Tests of Materials." Gus. C. Henning.

Vol. xviii., p. 849: "A Mirror Extensometer." Gus. C. Henning.

Vol. xviii., p. 1020: "Autographic Recording Apparatus for Use in Testing Materials." Thomas Gray.

‡ *Martens' Handbook on Testing Materials*, par. 679–683.

§ Ibid.

‖ *Transactions* A. S. M. E., vol. xviii., p. 849.

¶ *Transactions* A. S. M. E., vol. xviii., p. 823.

that the pressure necessary to hold them in place on the test piece is provided by spring-cushioned pointed screws symmetrically placed in the frames, so that this pressure cannot produce any distortion of them, and insures uniform identical adjustment and position of the instrument on the test piece under all changes of shape of the latter during test. The upper frame carries a pair of symmetrical hardened rollers ground to an exact diameter, supported on their centres in adjustable bushings, hence preventing all displacement of the rollers relative to the points of attachment on the test piece, so common in other similar instruments.

3. The lower frame carries pressure springs symmetrically placed, and a pair of parallel tubes used to hold distance pieces. The operation of the instrument is automatic and very simple,

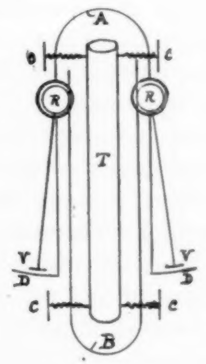


Fig. 253.

and is, therefore, free from any influence of the observer; it is shown in principle by Fig. 253.

At *A* and *B*, on the test piece *T*, two frames are clamped by means of spring-cushioned pointed screws *C*. Frame *A* carries rollers *R*; and frame *B*, springs or bars *S*. Frame *A* also carries graduated arcs *D*, while the rollers carry verniers to these arcs *V* in pairs, on opposite sides of the test piece. As the latter changes length, *A* and *B* change their relative positions, carrying on the one hand the rollers *R*, and on the other the bars *S* with them. As the bars *S* bear on the rollers *R*, the latter are caused to revolve, thus carrying the verniers *V* with them, moving in opposite directions over the arcs *D* rigidly connected to the frame *A*. As the test piece *T* stretches, the verniers *V* will

move away from the test piece; and, again, as the test piece shortens, the verniers *V* will move toward the test piece; therefore, one-half the sum of the readings will give a reading as though the instrument were mounted on the axis of the test piece. It is necessary to make observations of changes of length on two opposite superficial elements in order to obtain the true axial elongation, as the elements of the surface of material rarely change their lengths uniformly and equally under the application of stress, and instruments cannot be attached to the axis of the test pieces.

4. The proportions of diameter of roller, and divisions on arcs and verniers, are such that the readings on the verniers correspond to ten-thousandths of inches, and the divisions on the graduated arcs and verniers are at the same time exact numbers of minutes of arc; hence any good dividing engine will produce accurate scales. The latter, at the same time, permit of some adjustment should the diameters of rollers be dissimilar or not quite correct. If a roller be too small, it will cause the vernier to move too great a distance; and hence, if the radius of the latter be lessened, the vernier will travel over a lesser distance. So that to provide for such slight adjustment, which is almost necessary because rollers may have slight inherent errors, the arms carrying verniers and graduated arcs are made in two pieces, provided each with a sliding sleeve; if the roller is too large, the arms are lengthened; and shortened, if rollers are two small; marks are then made on the sleeves to indicate the correct relative positions of the arms sliding in them, and thus absolutely accurate readings can be obtained in all cases.

5. All that is necessary to do to obtain such accuracy is to mount the instrument on a rod and a tube, the former sliding in the latter, and actuated by a micrometer of known accuracy. As the micrometer is operated, the verniers move over the graduated arcs, and the arms of the two are then lengthened or shortened as the case may require, until the readings are identical on both arcs and on the micrometer. The relative positions of the vernier and arc arms are then marked on their respective holding sleeves, and thereafter adjusted to these marks.

6. When the test piece lengthens, the verniers move away from it, and hence the 0 on arc must be on the ends near it; when the test piece shortens, on the other hand, it is the reverse, and by interchanging the arcs the 0 marks will be located on their

ends away from the test piece; this interchangeability of arcs permits the use of graduation of half the length which would otherwise be necessary; the verniers are, of course, set to an initial reading near the 0 of each arc, at the beginning of each test. By the substitution of bars S and pins p of various lengths the instrument may be used on test pieces of any usual lengths, as it is provided with such for 2, 2½, 4, 6, and 8-inch lengths.

7. Fig. 254 shows the instrument as applied to an 8-inch test piece T in vertical position. A and B are the clamping frames; C_1, C_2, C_3, and C_4 the spring-cushioned hardened points; R_L and R_R the bushings which support the rollers; S_R and L_L the bars bearing on rollers; V_R and V_L the verniers carried by rollers; D_R and D_L the graduated arcs carried by the bushings, and p_1 and p_2 the distance pins used for adjustment to gauge length; U is a bent spring used to insure uniform pressure of bars S_R and S_L on the rollers and prevent slip.

In order that the moment of mass may not disturb the relative positions of verniers and arcs, due to jarring of the test piece or testing machine, the vernier and arc arms must always be placed in a position as nearly vertical as possible. The friction between bars S and rollers must be very slight, and hence the moment of mass of verniers and arcs, small as it is, because these parts are of aluminium, might cause slips between bars S and the rollers.

8. Fig. 255 shows the instrument as applied to a test piece in a horizontal position, and clearly illustrates that the verniers in this position will have only the minimum tendency to be disturbed by jarring; the ratio between the moment of friction on the roller and moment of mass of verniers and their arms will be very large, and hence prevent the slip of the rollers. As will be seen, the apparatus will therefore work equally well in a horizontal position.

In many other roller extensometers the rollers are held between two plates which are displaced relatively by change of length of test piece; hence the roller changes its position longitudinally by an amount equal to one half of such change of length; their indications are, therefore, totally incorrect. In this instrument, however, the rollers can only revolve on fixed centres, and as the verniers and arcs are carried by the rollers and their supporting bushings, the one is constrained to move in concentric arcs with the other and give correct motion in all positions.

9. In past experience it was found that, while the description of similar apparatus is very interesting and instructive, numberless

questions have been asked as to adjustment and application. In order that such questions may be fully answered for all those who

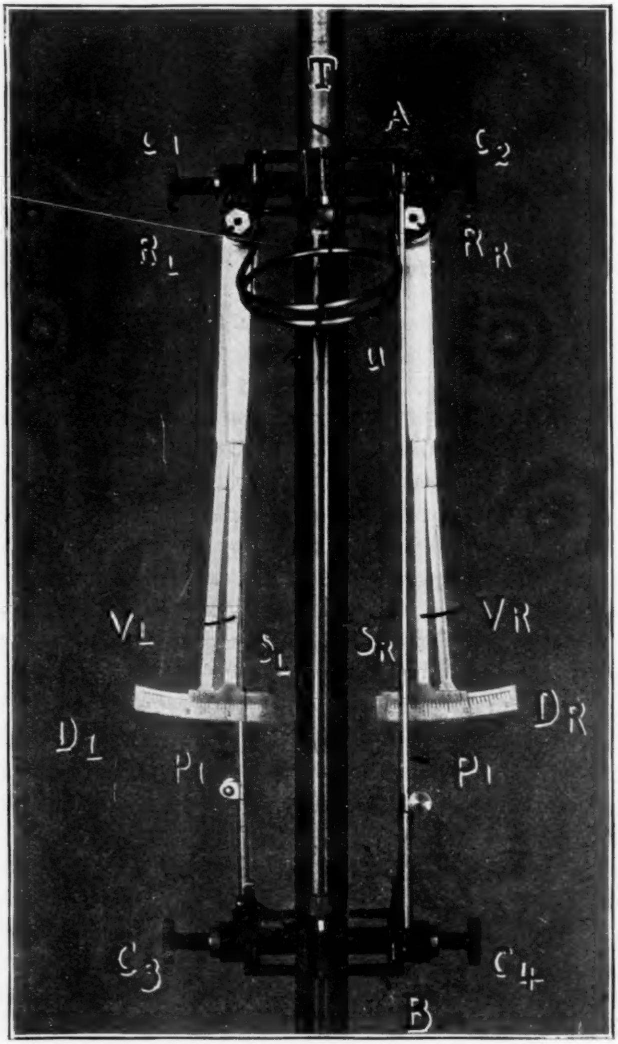


FIG. 254

refer to the *Transactions* for information about the apparatus, these points are here briefly explained in detail.

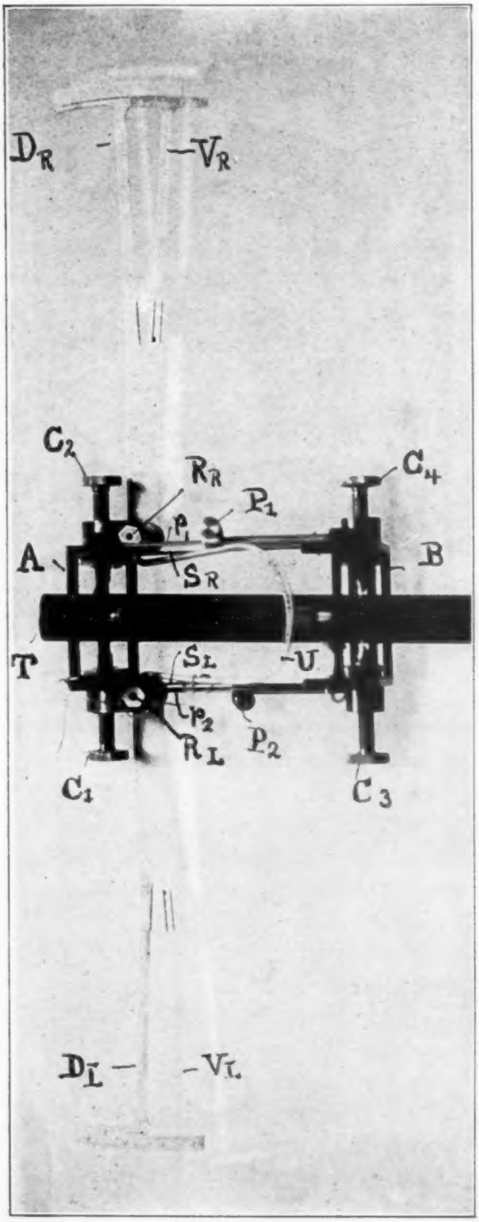


FIG. 255.

Adjustment.

(*a*) Clamp the distance pins P_1 and P_2 of the desired gauge length so that the scribed lines and the upper surfaces of tubes on frame B, through which they pass, are flush.

(*b*) Attach the side bars S_R and S_L with emery-covered surface placed outwardly, and of the desired gauge length, so that they stand parallel to each other and normal to the bottom surface of frame B.

(*c*) Draw out the divided arcs D_R and D_L, as well as the verniers V_R and V_L, until their ends are flush with the marks on the sleeves in which they slide.

(*d*) Place the arcs in position, as shown in Fig. 254 or as in Fig. 255.

(*e*) For *tension* tests, set the arcs with 0 toward the test piece.

(*f*) For *crushing* tests, set the arcs with 0 away from the test piece.

(*g*) Adjust the attaching points C_1, C_2, C_3, and C_4 so that the distance between them is about $\frac{1}{8}$ inch less than the thickness of the test piece.

10. *Application.*

(*a*) Open both frames A and B after removing taper plugs.

(*b*) Place lower frame B about the test piece after it has been firmly gripped by the jaws of the testing machine, and lock it by inserting the taper plug, great care being exercised to have the points C_3 and C_4 bear on the opposite centre lines when the test piece is cylindrical, and that the axis of screws C_3 and C_4 is normal to axis of test piece T in all cases. When in this position, the screws are advanced until their cushioning springs are flattened about $\frac{1}{16}$ inch; by moving these screws in the same direction the apparatus can be made to be precisely concentric with the test piece.

(*c*) The upper frame A is now carefully placed around the test piece T, locked, screws P clamping pins p_1, p_2, so that the instrument acts as a unit, and then moved forward or back until the screws C_1 and C_2 are truly opposite the axis of the test piece; the screws are then advanced until the cushioning springs are flattened $\frac{1}{16}$ inch and the apparatus is concentric with the test piece; if the lower frame has been properly adjusted, the apparatus will then be in proper position. In placing the upper frame, care must be had not to strike either verniers or arcs, and that the springs S_R and S_L bear on the inner surfaces of the rollers R_R and R_L. Now free pins P by releasing clamping screws.

(*d*) The spring U is then made to bear on the bars S_R and S_L, at a point slightly above the axis of the rollers; the bearing pressure of this spring must be very light.

(*e*) The verniers V_R and V_L are now adjusted so that their 0 marks are nearly opposite those on the arcs, and initial readings taken on both verniers and scales. The readings on verniers are $\frac{1}{10000}$ inch; so that a reading of 1.4 on the arc, and coincidence of line 3 on the vernier, with a division on the arc, will be an actual reading of 0.0143 inch, etc.

11. The actual axial change of length of the test piece is obtained by finding the average of differences of both right and left readings from the initial readings, or is one-half the sum of both differences.

In order to take readings with this instrument, definite loads are applied to the test piece under which readings are taken. The instrument is, however, equally useful for the determination of the yield point of materials.

For this purpose it is not necessary to take readings of change of length of test pieces, but merely to observe the rate at which such change takes place. During the elastic period, and under uniformly increasing loads, changes of length are uniform, and hence the verniers will move at a uniform rate over the arcs. Upon approaching the yield point, however, the rate of change of length suddenly increases rapidly, in which case the verniers will move at an increased rate of speed over the arcs. This more rapid motion of the verniers is independent of the operation of the testing machine, and continues under increasing and decreasing loads, and when the beam is not kept in true balance. It is not affected by the inertia of the testing machine, as may be the case with so-called "drop of beam" or fall of the pressure gauge.

Such an instrument is almost indispensable for the determination of the yield point of materials when making tests with the Emery testing machines, in which it is almost impossible to take accurate account of the "drop of beam" unless taking unusual precautions, or proceeding at a rate which is too slow for purposes of practical testing.

DISCUSSION.

Mr. James M. Dodge.—I would like to ask Mr. Henning if there is any danger of a rupture destroying this apparatus, or do you remove it?

Mr. Henning.—Instruments of precision must always be removed immediately after the yield point, because such instruments are not intended for anything more than determining elastic changes of shape. The only instrument which is used up to the instant of rupture is the autographic recorder. But all instruments of precision cannot stand the rapidity of action of a test piece when it stretches permanently immediately after the yield point, nor the impact or recoil at the instant of rupture—the instrument would be ruined.

No. 944.*

A PROPOSED STANDARD FOR MACHINE SCREW THREAD SIZES.

BY CHARLES C. TYLER, PITTSBURG.
(Member of the Society.)

1. Among the members of the American Society of Mechanical Engineers identified in a practical way with any manufacturing enterprise, there are probably very few who have not experienced more or less difficulty in obtaining commercial machine screws, purchased at different times, which would fit properly in holes tapped by the regular taps sold by the small tool manufacturers. The size of machine screws referred to more particularly in this paper are those less than one-half inch in diameter and designated by "screw gauge numbers." The variations found in the diameter, pitch and form of thread in these sizes, which are not serious to those using only a few hundred screws per year, become a source of large expense and extreme exasperation to those using them by the hundreds of thousands. The whole trouble seems to lie in the fact that there are no recognized basic reference standards having a generally accepted form of thread and diameter, and without them reliable reference, working or limit gauges cannot be exactly reproduced.

2. The diameters of the threaded portion of small machine screws are at present designated by arbitrary gauge numbers. In one respect these numbers are more reasonable than those of the many wire and sheet metal gauges, in that the larger numbers represent the larger screws. The catalogue of the Brown & Sharpe Manufacturing Company contains a "Table of Decimal Equivalents of Screw Gauge for Machine and Wood Screws," and it is there stated that "the difference between consecutive sizes is .01316 inch," a difference not easily calibrated by the ordinary

* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

measuring instruments. If the diameter of screw gauge No. 1 had been established as .01316 inch and the other numbers had been simply multiples thereof, the actual diameter of any number would have been easy to determine; but screw gauge No. 1 has a diameter of .071 inch, and the zero of the gauge is .05784 inch. Without the table the diameter of any gauge number can be found by multiplying the number by .01316 inch and adding .05784 inch.

3. The pitches, or number of threads per inch, of small machine screws are apparently standardized only for the sizes having even numbers; but the manufacturers carry in stock screws and taps having a number of different pitches for each size.

The form of thread at present used by the screw and tap manufacturers is not easily determined and may well be considered an unknown quantity and classed as a mongrel. An examination of many screws of the same and different sizes, made by the same and different manufacturers, has resulted in finding the top and bottom of the threads to be sharp, rounded or flat, and the angle of the threads very uncertain, although alleged to be 60 degrees.

FORM OF THREAD.

4. Any new standard for screws or bolts of any size must have primarily a practical form of thread to meet with the endorsement of progressive mechanical engineers. The writer, therefore, suggests for the Basic Reference Standards of machine screws the Seller's or Franklin Institute form of thread, which has an angle of 60 degrees and a truncation or flat on the top and bottom equal to one-eighth of the pitch of thread. In addition to its adoption by the United States Navy Department, the many associations, societies and manufacturing establishments in this country as the standard for bolts, nuts and screw threads, this form of thread was also adopted for machine screws by the International Congress for Standardizing Threads, held at Zurich, October 2d, 3d and 4th, 1898. It is a form capable of being exactly reproduced, is easily maintained and the only practical one in existence which will insure interchangeability. This form of thread is suggested for the basic reference standards only—for machine screws and machine screw taps some modifications of the form will be presented later which are worthy of consideration.

DIAMETERS OF SCREWS.

5. The present screw gauge has 30 numbers; No. 1 is .071 inch diameter, and No. 30 is .45264 inch diameter; the even numbered sizes being in more general use, except for the very small sizes. The writer suggests for the standard diameters of small machine screws the fifteen diameters, from .050 inch to .250 inch inclusive shown in the sixth column of Table I. These diameters were selected from among the sizes of the Decimal

TABLE I.

Present Diameters and Threads per Inch of Small Machine Screws. *The difference between consecutive sizes is* .01316.					Suggested Diameters and Threads per Inch of Small Machine Screws.		
Screw Gauge No.	Stand. No. of Threads per Inch.	Threads also Furnished.	Diam. in Fractional Parts of In.	Diameter in Decimal Parts of Inch.	Diameter in Decimal Parts of Inch.	Stand. No. of Threads per Inch.	Pitch.
......	......	......	......	......	.050	72	.013889
......	......	......	......	......	.060	64	.015625
1	......	56,60,64,72.	$\frac{1}{16}$	.07100	.070	60	.016667
$1\frac{1}{2}$	......	56.	$\frac{5}{64}$	.07758	.080	56	.017857
2	56	48,64.	$\frac{5}{64}$	.08416	.090	52	.019231
3	......	40,44,48,56.	$\frac{3}{32}$	.09732	.100	48	.020833
4	36	30,32,40,42,44,48.	$\frac{7}{64}$	.11048	.110	44	.022727
5	......	30,32,36,40,44,48.	$\frac{1}{8}$	.12364	.125	40	.025000
6	32	30,36,38.40,44,48.	$\frac{9}{64}$	.13680	.135	40	.025000
7	......	24,28,30,32,36,40.	$\frac{5}{32}$	.14996	.150	36	.027778
8	32	24,30,36,40,44.	$\frac{5}{32}$	.16312	.165	32	.031250
9	......	24,28,30,32.	$\frac{11}{64}$	.17628	.180	32	.031250
10	24	20,22,28,30,32,36.	$\frac{3}{16}$	.18944			
11	.....	22,24,28,30.	$\frac{13}{64}$	.20260	.200	30	.033333
12	24	20,22,26,28,30,32,34,36.	$\frac{7}{32}$	.21576	.220	28	.035714
13	......	20,22,24,32.	$\frac{15}{64}$	.22892			
14	20	16,18,22,24,26.	$\frac{15}{64}$	.24208	.250	24	.041667
15	.....	18,20,22,24.	$\frac{1}{4}$	.25524			
16	18	16,20,22,24,26.	$\frac{17}{64}$	.26840	......	......	....
17	......	16,18,20.	$\frac{9}{32}$	.28156	.28125	22	.045455
18	18	16,20,22,24,26.	$\frac{19}{64}$	.29472	....	......	....
19	......	16,18,20,22,24.	$\frac{5}{16}$	.30788	.3125	20	.050000
20	16	18,20,22,24.	$\frac{21}{64}$	.32104			
22	16	18.	$\frac{11}{32}$	.34736	.34375	20	.050000
24	16	14,18,20,22,24.	$\frac{3}{8}$	.37368	.375	18	.055556
26	16	14.	$\frac{13}{32}$	.40000	.40625	18	.055556
28	14	16.	$\frac{27}{64}$	.42632	.4375	16	.062500
30	14	16.	$\frac{29}{64}$	.45264	.46875	16	.062500
......	......	......	......	......	.500	14	.071429

Gauge, are in thousandths of an inch and can be easily calibrated by the ordinary measuring instruments.

The sizes of the Decimal Gauge have already been recommended by the American Society of Mechanical Engineers and adopted by the American Railway Master Mechanics' Association, and the American Steel Manufacturers' Association. Eight diameters larger than .250 inch, advancing by thirty-seconds of an inch, are given in the tables simply to fully cover the range of the screw gauge numbers.

PITCH OF SCREWS.

6. The pitch, or number of threads per inch, of small machine screws varies with the work for which they are used; very thin pieces requiring finer pitches than thick ones. That variations in pitch are called for is shown by the assortment given for each diameter of screw. The writer suggests for the standard pitches of small machine screws those given in the seventh and eighth columns of Table I. These pitches were determined by the formula

$$p=0.23\sqrt{d+0.625}-0.175.$$
$$p=\text{pitch},\ d=\text{diameter}.$$

This formula was proposed by Mr. George M. Bond in 1882, and referred to in a lecture delivered by him before the Franklin Institute, February 29, 1884, on the subject "Standards of Length as Applied to Gauge Dimensions." It differs from the one used for the determination of the pitch of United States Standard bolts, nuts and screw threads only in its coefficient, which is 0.23 instead of 0.24, and increases the number of threads per inch more rapidly as the diameter decreases.

The exact pitches derived from the formula are given in Table II., and the suggested standard pitches will be found to closely approximate the derived pitches.

TABLE II.

PITCH DETERMINATIONS BY THE FORMULA

$p=0.23\sqrt{d+0.625}-0.175.$

p=pitch, d=diameter.

Diameter in Decimal parts of inch.	Pitch obtained by formula.	Equivalent threads, per inch.	Suggested standard number threads, per inch.
.050	.013968	71.6	72
.060	.015348	65.15	64
.070	.016728	59.8	60
.080	.018108	55.22	56
.090	.019488	51.31	52
.100	.020822	48.02	48
.110	.022179	45.08	44
.125	.024080	41.53	40
.135	.025514	39.19	40
.150	.027469	36.4	36
.165	.029424	33.95	32
.180	.031356	31.89	32
.200	.033909	29.46	30
.220	.036439	27.44	28
.250	.040142	24.91	24
.28125	.043960	22.75	22
.3125	.047686	20.97	20
.34375	.051366	19.46	20
.375	.055000	18.18	18
.40625	.058565	17.07	18
.4375	.062061	16.11	16
.46875	.065557	15.25	16
.500	.068938	14.5	14

MODIFICATION OF THREAD FORM.

7. Screws of any size fit better in the angle of the thread in tapped holes if there is clearance at the top and bottom of the threads. Bolts and nuts, when made with threads in exact accordance with the United States standard thread, do not have this clearance, yet by a slight modification of this form of thread, clearance can be obtained and still preserve the desirable feature of the practical interchangeability of thread sizes. A change in the amount of truncation or flat at the bottom of the thread of screws and at the top of the thread of taps would be the only modification of the United States standard thread necessary to obtain the desired clearance; but for any given size the diameter of the screws and taps should remain the same when measured in the angle of the thread.

For screws, the form of thread suggested has an angle of 60 degrees, a flat at the top of the thread 1-8 of pitch, and a flat at the bottom of the thread 1-16 of pitch.

For taps the form of the thread suggested has an angle of 60 degrees, a flat at the top of the thread 1-16 of pitch, and a flat at

the bottom of the thread 1-8 of pitch. A screw and sectional tapped nut and a sectional screw and nut having these modified forms of thread, giving clearance at the top and bottom of the thread, are shown in Fig. 256.

When a screw and tap measure the same diameter in the angle of the thread, the tap has a larger external diameter than the screw if the top of the thread is flatted 1-16 of pitch, and these increased

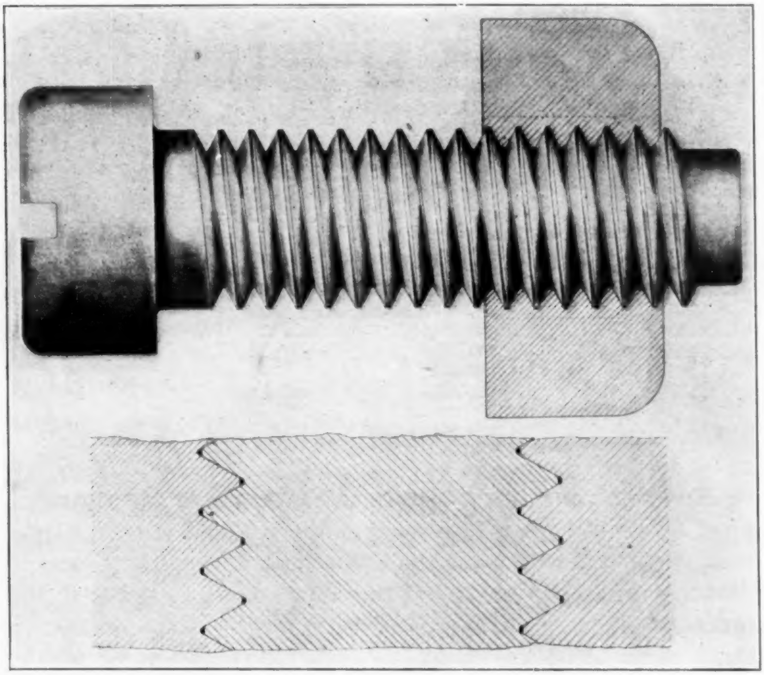


FIG. 256.

external diameter of taps for each size of screw are shown in the first column of Table III.

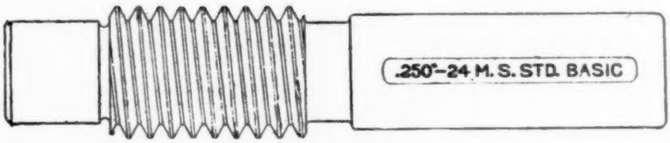
STANDARD REFERENCE THREAD GAUGES.

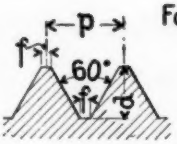
8. To insure the interchangeability of machine screws and taps, a practical system of gauging should be provided and ultimate standards of reference are desirable, particularly in cases of disputed thread sizes. The modifications of the forms of thread for screws and taps to give clearance, each being based on the

United States Standard thread, makes it seem desirable to provide three sets of standard reference thread gauges for each gauge diameter; one basic, one for screws, and one for taps.

BASIC STANDARD REFERENCE THREAD GAUGES.

9. The writer would suggest as the foundation of the system a set of Basic Standard Reference thread gauges; these gauges to be made of unhardened tool steel, to represent exactly, in every detail, the United States form of thread, the diameter at the





Form of Thread

Formula $\begin{cases} \text{p-pitch} = \dfrac{1}{\text{number of threads per inch}} \\ \text{d-depth} = \text{p} \times .6495 \\ \text{f-flat} = \dfrac{\text{p}}{8} \end{cases}$

BASIC STANDARD REFERENCE THREAD GAUGES.

FIG. 257.

top of thread, the diameter at the bottom of thread, and the correct pitch; each basic standard gauge to have plainly marked thereon the diameter, number of threads per inch and M. S. Standard Basic (Machine Screw Standard), as shown in Fig. 257, which also gives the thread formula.

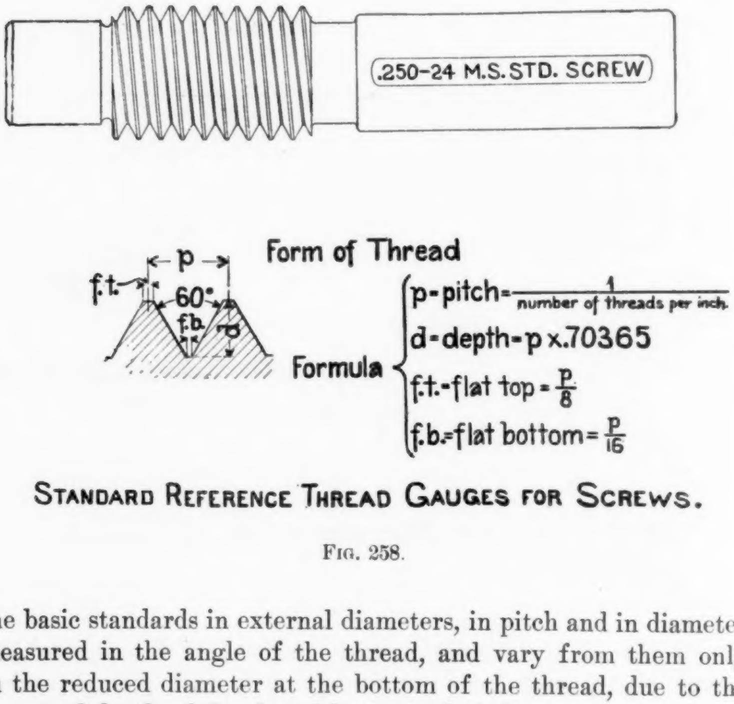
The basic standards should be used only for comparative calibration in the making of the reference standards for screws and taps.

STANDARD REFERENCE THREAD GAUGES FOR SCREWS.

10. These gauges are to be made of unhardened tool steel, to represent exactly, in every detail, the modified United States form

of thread (having an angle of 60 degrees, a flat at the top of thread 1-8 of pitch and a flat at the bottom of thread 1-16 of pitch), the diameter at the top of thread, the diameter at the bottom of thread, and the correct pitch. Each standard for screw gauge is to have plainly marked thereon the diameter, number of threads per inch, and M. S. Standard Screw, as shown in Fig. 258, which also gives the thread formula.

The standards for screw gauges should be exact duplicates of



STANDARD REFERENCE THREAD GAUGES FOR SCREWS.

FIG. 258.

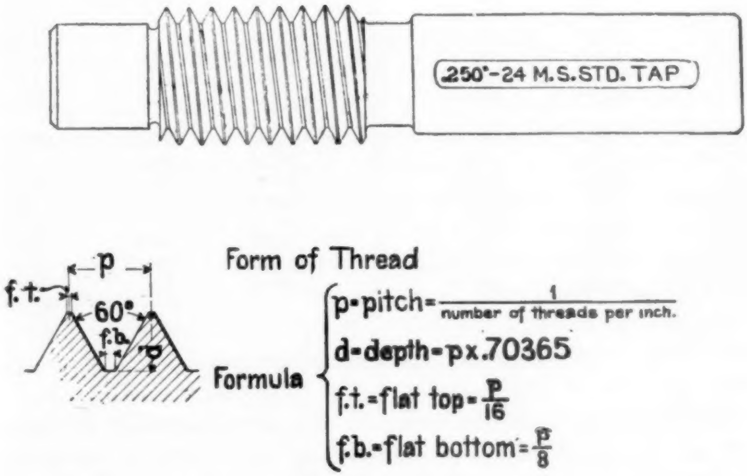
the basic standards in external diameters, in pitch and in diameter measured in the angle of the thread, and vary from them only in the reduced diameter at the bottom of the thread, due to the increased depth of the thread by 1-16 of pitch.

STANDARD REFERENCE THREAD GAUGES FOR TAPS.

11. These gauges are to be made of unhardened tool steel, to represent exactly, in every detail, the modified United States form of thread (having an angle of 60 degrees, a flat at the top of thread 1-16 of pitch and a flat at the bottom of the thread 1-8 of pitch), the diameter at the top of the thread, the diameter at the bottom

of the thread, and the correct pitch. Each standard for tap gauges is to have plainly marked thereon the diameter, number of threads per inch, and M. S. Standard Tap, as shown in Fig. 259, which also gives the thread formula.

The standard for tap gauges should be exact duplicates of the Basic Standards in diameter at the bottom of the thread, in pitch, and in diameter measured in the angle of the thread, and vary from them only in the increased external diameter at the top of the thread, due to the increased height of the thread by 1-16 of the pitch. Standard Reference thread gauges are given in Table III.



STANDARD REFERENCE THREAD GAUGES FOR TAPS.

FIG. 259.

Standard Reference thread gauges for screws and taps should be used *only* for comparative calibration in the making of working gauges for screws and taps, and to detect by calibration the wear of the working gauges in actual use. If used only for the above purposes, these gauges would remain standards indefinitely; but if, through accident or carelessness, they are injured, new reference gauges could be exactly reproduced, provided the set of Basic Standards had been carefully preserved in a safe or vault where all such standards should be kept.

TABLE III.

STANDARD REFERENCE THREAD GAUGES.

Standard Gauges for Taps.		Basic Standard Reference Gauges.			Standard Gauges for Screws.	
Diameter Top of Thread.	Diameter at Root of Thread.	Diameter Top of Thread.	Threads per Inch.	Diameter at Root of Thread.	Diameter Top of Thread.	Diameter at Root of Thread.
.05151	.03196	.050	72	.03196	.050	.03045
.06170	.03971	.060	64	.03971	.060	.03801
.07180	.04835	.070	60	.04835	.070	.04655
.08194	.05681	.080	56	.05681	.080	.05487
.09208	.06502	.090	52	.06502	.090	.06294
.10226	.07294	.100	48	.07294	.100	.07068
.11246	.08048	.110	44	.08048	.110	.07802
.12771	.09253	.125	40	.09253	.125	.08982
.13771	.10253	.135	40	.10253	.135	.09982
.15302	.11393	.150	36	.11393	.150	.11091
.16838	.12441	.165	32	.12441	.165	.12103
.18338	.13941	.180	32	.13941	.180	.13603
.20361	.15670	.200	30	.15670	.200	.15309
.22387	.17361	.220	28	.17361	.220	.16974
.25452	.19588	.250	24	.19588	.250	.19136
.28623	.22226	.28125	22	.22226	.28125	.21733
.31791	.24755	.3125	20	.24755	.3125	.24214
.34921	.27885	.34375	20	.27885	.34375	.27344
.38102	.30284	.375	18	.30284	.375	.29682
.41232	.33414	.40625	18	.33414	.40625	.32812
.44427	.35632	.4375	16	.35632	.4375	.34955
.47557	.38762	.46875	16	.38762	.46875	.38085
.50774	.40722	.500	14	.40722	.500	.39948

WORKING GAUGES FOR SCREWS.

12. The important measurement of a screw thread is its diameter as compared with the diameter of the standard reference thread gauge for screws *when measured in the angle of the thread.* A screw thread may be quite a little smaller than the gauge size in external diameter and made almost a sharp V at the bottom and still fit satisfactorily in a standard tapped hole, provided it is the correct diameter in the angle of the thread.

The ordinary internal thread limit gauges for small diameters without adjustment for taking up wear, require special taps for their manufacture, and change size so rapidly that they are hardly practical; when provided with adjustment for taking up wear they become quite expensive, and to insure correctness of size and to guard against being tampered with, they must be frequently inspected; the use of either style of gauge for the inspection of screws is a slow process.

The external diameter of the threaded portion of a screw can be

easily calibrated by the ordinary micrometer caliper, or limit hole or notched gauges can be satisfactorily used. To determine the diameter of screws when measured in the angle of the thread, the writer suggests the use of some special indicating instrument by which the diameter of the screw may be quickly compared with the diameter of the Working Gauges for screws.

The working gauges for screws should be unhardened and exact duplicates of the standard reference thread gauges for screws, in external diameter, in diameter at the bottom of thread, in pitch, and in diameter measured in the angle of the thread; each working gauge for screws to have plainly marked thereon the diameter, number of threads per inch, and "M Screw."

WORKING GAUGES FOR TAPS.

13. The measurement of taps is fully as important as the measurement of screws. The tap, however, may be quite a little larger than the gauge size in external diameter, in fact made sharp V at the top, and somewhat larger in diameter at the bottom of the thread (with wider flat), and still tap a hole into which a standard threaded screw would fit satisfactorily, provided it is the correct diameter in the angle of the thread. The suggested method of determining the diameter of taps when measured in the angle of the thread is the same as for screws; *i.e.*, the use of some special indicating instrument by which the diameter of the tap may be quickly compared with the diameter of the Working Gauges for taps.

The working gauges for taps should be unhardened and exact duplicates of the standard reference thread gauges for taps, in external diameter, in diameter at the bottom of thread, in pitch, and in diameter measured in the angle of the thread; each working gauge for taps to have plainly marked thereon the diameter, number of threads per inch, and "M. S. Taps."

The handles of all working gauges should be of some form easily distinguished from that of the reference gauges.

LIMITS OF VARIATION IN SCREW AND TAP DIAMETERS.

14. It is not to be expected that the thread sizes of small screws and taps can be made commercially to correspond exactly with the

gauge dimensions, and established limits of variation may prevent controversy if the sizes of either are in dispute.

To insure the satisfactory fit of a screw in a tapped hole, it seems obvious that *screws should never be larger* than the working gauges, though they may be a trifle smaller; and that *taps should never be smaller* than the working gauges, though they may be somewhat larger. The variations from the working gauge sizes, therefore, should be always minus for the screws, and plus for the taps.

For screws and taps of the small diameters under consideration the limits may well be determined by some multiple of the pitch, and the writer suggests — pitch x 0.05 — as a practical formula.

The limits of variation in the diameters of machine screws and taps when measured in the angle of the thread as determined by the formula are shown in Table IV.

TABLE IV.

LIMITS OF VARIATION IN DIAMETERS OF MACHINE SCREWS AND TAPS WHEN MEASURED IN ANGLE OF THREAD.

Formula, Limit = pitch × 0.05.

Taps.	Sizes.	Screws.	Sum of Limits.
+.0007	.050	−.0007	.0014
+.0008	.060	−.0008	.0016
+.0008	.070	−.0008	.0016
+.0009	.080	−.0009	.0018
+.0010	.090	−.0010	.0020
+.0011	.100	−.0011	.0022
+.0012	.110	−.0012	.0024
+.0013	.125	−.0013	.0026
+.0013	.135	−.0013	.0026
+.0014	.150	−.0014	.0028
+.0016	.165	−.0016	.0032
+.0016	.180	−.0016	.0032
+.0017	.200	−.0017	.0034
+.0018	.220	−.0018	.0036
+.0021	.250	−.0021	.0042
+.0023	.28125	−.0023	.0046
+.0025	.3125	−.0025	.0050
+.0025	.34375	−.0025	.0050
+.0028	.375	−.0028	.0056
+.0028	.40625	−.0028	.0056
+.0031	.4375	−.0031	.0062
+.0031	.46875	−.0031	.0062
+.0036	.500	−.0036	.0072

15. For the rapid inspection of screws or taps to determine if they are within these limits of variation, the method suggested is their comparison by calibration with the working gauges by the use of the special indicating instrument, which will instantly give the correct reading. For the limits of variation of the ex-

ternal thread diameters of screws and taps the formula—pitch x 0.1 is suggested, and the derived limit sizes by this formula are shown in Table V.

TABLE V.

LIMITS OF VARIATION IN EXTERNAL THREAD DIAMETERS OF MACHINE SCREWS AND TAPS.

Formula = Pitch × 0.1.

Taps.	Sizes.	Screws.	Sum of Limits.
+.0014	.050	−.0014	.0028
+.0016	.060	−.0016	.0032
+.0016	.070	−.0016	.0032
+.0018	.080	−.0018	.0036
+.0020	.090	−.0020	.0040
+.0022	.100	−.0022	.0044
+.0024	.110	−.0024	.0048
+.0026	.125	−.0026	.0052
+.0026	.135	−.0026	.0052
+.0028	.150	−.0028	.0056
+.0032	.165	−.0032	.0064
+.0032	.180	−.0032	.0064
+.0034	.200	−.0034	.0068
+.0036	.220	−.0036	.0072
+.0042	.250	−.0042	.0084
+ 0046	.28125	−.0046	.0092
+.0050	.3125	−.0050	.0100
+.0050	.34375	−.0050	.0100
+.0056	.375	−.0056	.0112
+.0056	.40625	−.0056	.0112
+.0062	.4375	−.0062	.0124
+.0062	.46875	−.0062	.0124
+.0072	.500	−.0072	.0144

LIMITS OF VARIATION IN SCREW AND TAP PITCHES.

Screws and taps often have threads which have an incorrect pitch or lead, and therefore do not fit properly. These errors are probably due to the warping of dies and taps during the tempering process. Slight changes in lead are not very serious, but if limits be established there need be no dispute later by interested parties. The limits suggested are 0.002 inch plus or minus, for either screws or taps, for one inch of length.

By suitable jaws the errors of pitch may be determined by using the same instrument as for calibrating in the angle of thread.

TABLE VI.

THREAD MEASUREMENTS FOR MACHINE SCREWS AND TAPS.

Diameter of screw.	Number threads, per inch.	Pitch.	Width of flat at top of thread, $\frac{1}{8}$ of pitch.	Width of flat, at bottom of thread, $\frac{1}{16}$ of pitch.	2 times depth U. S. Stand. thread.	2 times depth stand. machine screw thread.
.050	72	.013889	.001736	.000868	.01804	.01955
.060	64	.015625	.001953	.000977	.02029	.02199
.070	60	.016667	.002083	.001042	.02165	.02345
.080	56	.017857	.002232	.001116	.02319	.02513
.090	52	.019231	.002404	.001202	.02498	.02706
.100	48	.020833	.002604	.001302	.02706	.02932
.110	44	.022727	.002841	.001421	.02952	.03198
.125	40	.025000	.003125	.001563	.03247	.03518
.135	40	.025000	.003125	.001563	.03247	.03518
.150	36	.027778	.003472	.001736	.03608	.03909
.165	32	.031250	.003906	.001953	.04059	.04397
.180	32	.031250	.003906	.001953	.04059	.04397
.200	30	.033333	.004167	.002084	.04330	.04691
.220	28	.035714	.004464	.002232	.04639	.05026
.250	24	.041667	.005208	.002604	.05412	.05864
.28125	22	.045455	.005682	.002841	.05904	.06397
.3125	20	.050000	.006250	.003125	.06495	.07036
.34375	20	.050000	.006250	.003125	.06495	.07036
.375	18	.055556	.006945	.003473	.07216	.07818
.40625	18	.055556	.006945	.003473	.07216	.07818
.4375	16	.062500	.007813	.003907	.08118	.08795
.46875	16	.062500	.007813	.003907	.08118	.08795
.500	14	.071429	.008929	.004465	.09278	.10052

SPECIAL INDICATING INSTRUMENTS.

16. There are in use in the different watch factories several kinds of rack and pinion gauges, of both the horizontal and vertical types, for calibrating the diameter, length and thickness of watch parts. The horizontal or " fine " gauge might be readily adapted for the special indicating instrument and such a modified gauge is shown in Fig. 260. The spindle passing through the circular portion of the instrument has a rack cut upon it which engages with a short train of wheels, giving a circular motion to the hand.

The ratio of the rack and wheels in this gauge is such that a rotation of the hand equal to one division on the dial represents a longitudinal movement of the spindle of 0.001 inch. To one end of the spindle is attached a jaw having a single V edge with an angle of 60 degrees and properly flatted, so that it cannot touch the bottom of the thread of a screw having 24 threads per inch; this jaw can be adjusted lengthwise upon the spindle by means of a screw in the end of the spindle. The stationary jaw has two parallel V edges with angles of 60 degrees properly flatted and the edges correctly spaced for the pitch. (For different pitches the stationary jaw must be changed; or better still, provide a

FIG. 260.

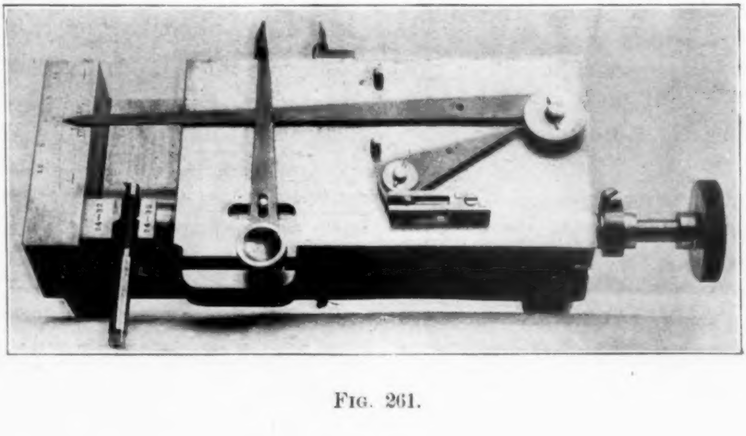


FIG. 261.

complete gauge for each pitch.) In measuring a screw the contact is insured by a long helical spring connecting with the case and spindle, which gives a nearly uniform pressure between the jaws. To compare the diameter of a screw with its proper working gauge, insert the gauge between the jaws and move the jaw with single V edge by the screw until the hand registers 0; after this adjustment, insert the screw and its variation from the diameter of the gauge will be indicated by the hand upon the dial.

The small tool department of the Pratt & Whitney Company has for several years used the instrument shown in Fig. 261 to determine the variations in thread diameters of taps under one-half inch diameter.

If the accuracy of either style of instrument shown should be questioned, the fact to be borne in mind is that the *exact* diameter of a screw when measured in the angle of the thread is not essential—it is that diameter when compared with the diameter of the gauge that is the important measurement.

DISCUSSION.

Mr. Tyler.—It may be of interest to the members of the Society to present some recent comparisons between commercial machine screws and taps, and a set of steel plug gauges.

The gauges were made about eighteen months ago. Their diameters over the top of thread were in accordance with the numbered gauge diameters, and the threads were a sharp V in form. The screws, of both brass and steel, were purchased from the American Screw Company—taken from regular storeroom stock—and five gross of each size were compared with the gauges. The taps were bought within two months from the J. M. Carpenter Tap and Die Company, Pratt & Whitney Company, Morse Twist Drill and Machine Company, S. W. Card Manufacturing Company, and Standard Tool Company. Twelve taps of each screw-gauge size from each of the manufacturers named were compared with the gauges. (Taps were ordered from several other manufacturers, but had not been received two weeks ago.)

The comparison of eleven sizes of screws and taps was made by the use of the special indicating instrument shown in Fig. 261, measuring in the angle of the thread, and the results are given in the following table:

VARIATIONS FOUND IN COMMERCIAL MACHINE SCREWS AND TAPS WHEN MEASURED IN THE ANGLE OF THREAD.

SIZE.	SCREWS.			TAPS.			COMBINED.		
Gauge No.	Max.	Min.	Total	Max.	Min.	Total	Max.	Min.	Total.
	in.	in.	in.	in.	in.	in.	in.	in.	in.
2-64	+.006	—.002	.009	+.013	+.003	.010	+.013	—.002	.015
2-56	+.006	0.	.006	+.014	+.008	.006	+.014	0.	.014
4-40	+.012	—.002	.015	+.014	+.005	.009	+.014	—.002	.016
4-32	+.006	+.002	.004	+.012	+.009	.003	+.012	+.002	.010
6-32	+.006	0.	.006	+.014	+.002	.012	+.014	0.	.014
8-32	+.003	—.004	.007	+.008	+.001	.007	+.008	—.004	012
10-32	+.005	—.001	.006	+.010	+.002	.008	+.010	—.001	.011
10-24	+.004	—.002	.006	+.009	+.002	.007	+.009	—.002	.011
12-32	+.005	—.001	.006	+.013	+.004	.009	+.013	—.001	.014
12-24	+.008	—.002	.010	+.011	+.003	.008	+.011	—.002	.013
14-24	+.008	—.003	.011	+.013	+.004	.009	+.013	—.003	.016

It is well known that the gauges used are too small in diameter in the angle of thread, but they serve the purpose of showing the variations in size of the regular screws and taps, which can now be bought in the open market.

Mr. E. H. Neff.—The difficulties encountered by the author of this paper are matters of very common knowledge, but it would seem to me that nearly all which he mentions can be classed as defects in workmanship. It is unfortunate that he has not made plain whether his criticisms refer to screws in which the threads are cut with dies, or whether he is talking about screws with upset heads and rolled threads, such as will be obtained in the open market in packages when a cheap screw is wanted. The manufacturers of screws have been pressed to the limit for cheapness of selling price, so that there is little difference between the price of stock and the price of screws, and often this difference is in favor of the screws. All of the troubles he relates can be overcome by placing orders with screw manufacturers for the large quantities he uses, and specifying dimensions and the limits of accuracy required. If these specifications are submitted for bids I have no doubt the screw manufacturers would name a price which would enable them to fulfil the requirements. It is impossible to make a good article for the cost of the cheapest.

With reference to the variations in the form of thread, it is scarcely believable that this is the result of ignorance either as to proper angle or to the dimensions of the threads. On cheap screws, of course, if dies are used, they will be kept in service as long as possible before being discarded; in operating the automatic screw-machine department the operator will be compelled to keep as many machines going as he possibly can, so as to keep down the wage cost, and this means that the dies as well as other tools

will receive the minimum of attention. A neglected die means a dull one, and this in turn means threads with rounded, twisted sides, and with distorted pitches. A like situation exists as regards taps and dies where the element of cheapness has been run to the limit, with the result that the product is of little or no value.

My observation, covering several years in this class of work, has been that parties who send to tap and die manufacturers specifying the diameter of screw in thousandths and the number of threads per inch, have no difficulty whatever in obtaining exactly what they order. Such taps and dies, however, purchased of reputable manufacturers, will cost more than those turned out for indiscriminate sale in supply stores unless the special order is for a considerable number of one kind. It hardly seems reasonable to suppose that the large screw manufacturers or the large tap and die makers, who have competent engineering forces, are not perfectly familiar with the proportions of a standard thread, and have not the means of producing and reproducing these correctly *ad libitum.*

Referring to the question of measuring screws or taps, there is an instrument which has been made by the Brown & Sharpe Mfg. Co. for several years for this purpose, namely, their Screw Thread Micrometer Caliper (Fig. 262). This instrument is intended to establish screw sizes within as accurate limits as it is possible to measure with any micrometer reading in thousandths. It measures screws, taps, or gauges on the angle of the thread, giving the correct pitch diameter, which is read off directly and exactly on the caliper itself. Accompanying this micrometer are tables giving the correct pitch diameter for each standard-size screw with standard threads, either of the United States Standard form of thread or with the sharp " V " thread. If plug thread standards are not provided, the caliper can be set to the size given in the table, and used for a gauge to which to fit the screw. If you wish to compare a standard-plug gauge with a screw, it is only necessary to compare the readings on the screw and on the gauge. If you are making some odd-size screw, you can compute the correct pitch diameter so as to find out what the micrometer should read by subtracting from the nominal outside diameter the depth of one thread. If a screw with V threads, subtract the quotient of .866 divided by number of threads to 1 inch. For United States Standard threads, subtract the quotient of .6495 divided by number of threads to 1 inch.

I believe the presentation of this paper at this time will be a good thing for all concerned, because the least it can do will be to start an agitation which may result in screw manufacturers and screw users getting together on the question of quality and price to their mutual benefit. None of the reasons given would be

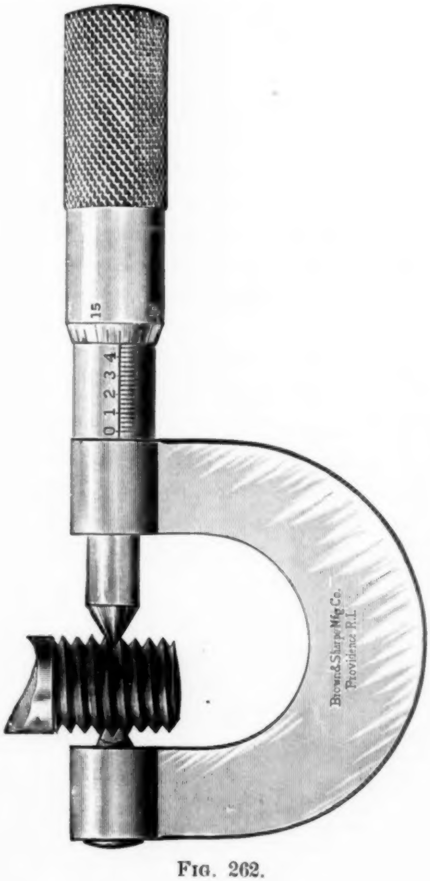


FIG. 262.

a sufficient excuse for adopting a totally different and new scheme of sizes for the screw-pitch gauge. We already have too many gauges, and if possible this number should be reduced. If any change is to be made, I believe the present screw gauge should be abandoned, and the American Standard Wire Gauge substituted therefor, using such of its numbers as will present a fairly uniform range of sizes from $\frac{1}{4}$ inch down. One gauge would then

cover both cases, and it would only be necessary to assign to each size of wire a suitable number of threads per inch.

I append hereto a table showing the standard I would suggest for the new screw list, but even this could be shortened to advantage by omitting all sizes over $\frac{1}{4}$ inch:

Present Screw Gauge. No.	In.	Threads per Inch.	Proposed Screw Gauge. No.	In.	Thread per Inch.
30	= .45264	14	0000	= .46	16
29	= .43948	......			
28	= .42632	14			
27	= .41316	......	000	= .40964	18
26	= .4000	16			
25	= .38684	......			
24	= .37368	16			
23	= .36052	......	00	= .3648	20
22	= .34736	16			
21	= .33420	......			
20	= .32104	16	0	= .32486	20
19	= .30788	......			
18	= .29472	18			
17	= .28156	......	1	= .2893	22
16	= .26840	18			
15	= .25524	......	2	= .25763	24
14	= .24208	20			
13	= .22892	......	3	= .22942	28
12	= .21576	24			
11	= .20260	......	4	= .20431	30
10	= .18944	24			
9	= .17628	......	5	= .18194	32
8	= .16312	32	6	= .16202	32
7	= .14996	......	7	= .14428	36
6	= .13680	32			
5	= .12364	......	8	= .12849	40
4	= .11048	36	9	= .11443	44
3	= .09732	......	10	= .10189	48
			11	= .09074	52
2	= .08416	56	12	= .08081	56
1	= .0710	......	13	= .07196	60
			14	= .06408	64
0	= .05784	......	15	= .05707	72

Mr. George M. Bond.—I would say, that from the experience I have had in the use of the United States Standard Thread, the adoption of that form of thread, 60 degrees included angle, flat, top, and bottom $\frac{1}{8}$ of the pitch, for the reference models or standards, certainly secures the conditions best adapted for maintaining the standard, as it does for originating it in case of the destruction or wear of the reference gauges.

The reduction of width of flat at the bottom of the thread of the screw gives the clearance at this point, and by having the tapped hole as produced by a tap which is larger in the outside diameter, the top of the thread being thus slightly less than $\frac{1}{8}$

the pitch, ensures a clearance at this point also. This is a feature necessary in the Sellers or United States Standard system of bolts and nuts, in order to obtain the practical interchangeability desired. Hence this form of thread will meet most admirably all the requirements of an interchangeable system for machine-screws as well, which does not at present exist.

The method suggested by Mr. Tyler in his paper for comparison of screws and of taps would seem to me to be particularly well adapted for the purpose, by measuring in the angle of the thread, as it is one which is necessary in the use of the United States Standard, because the actual contact or fit of the thread in the nut is and should be in the angle, not at top or bottom. Therefore, the adoption of the same principle for machine screws will give, from our experience, the greatest efficiency in the comparison of different screw sizes and of taps within limits that entirely are practicable.

It should be a source of satisfaction to all concerned to have the subject treated in this way, for I think it is in the right direction, especially avoiding the use of numbered sizes, which as we all know are not sufficiently definite for those who have been unfortunate enough to have to reconcile the vagaries of the various wire gauges based on arbitrary numbered sizes. By adopting the decimal diameters which Mr. Tyler proposes, the system covers the range and diameters adopted by the American Railway Master Mechanics' Association, up to and including $\frac{1}{4}$ of an inch, as being practically equivalent to the usual sizes of wire, and as the diameters are in thousandths of an inch, no confusion can possibly arise on this account.

It would, therefore, seem to me that the system advocated in the paper has elements in it commending it to the favorable consideration of both manufacturers of machine-screws and makers of taps, as well as the users of machine screws and machine-screw taps. It will certainly be a practical solution of the problem of interchangeability of so-called machine screws, within the limits that are necessary for a manufactured product.

Mr. Oberlin Smith.—This is an extremely important subject, and I most sincerely hope that the Society will appoint a committee to formulate and recommend a standard for machine screws. They are a perfect nuisance as they are now made. They are known by gauge numbers which do not mean anything, and which are different from the wire-gauge numbers of the Birmingham gauge,

or the Brown & Sharpe, or any other, except that some sizes may happen to agree. There is no reason why screws below $\frac{1}{4}$ inch in diameter should not be subject to the same rigid rules as are screws above that, according to the Franklin Institute or Sellers Standard. That standard never should have stopped at $\frac{1}{4}$ inch. I disapprove of the recommendation in this paper of flattening the thread at the top and bottom, except as it is done in the Sellers thread—that is, on the screw itself. Perhaps some regular clearance might be given to all nuts. While this committee is at it they might overhaul all screw threads in this particular. The Sellers Standard should be altered only in two or three of the smaller sizes, which should be of finer pitch than now. The thing that this committee should do if appointed is to make the series of pitches approximately correct from beginning to end, all the way down to watch-screws. This proposed table I see makes $\frac{250}{1000}$ which is $\frac{1}{4}$ of an inch, 24 threads per inch. If I remember aright, the Sellers Standard is 20 per inch.

This series may be really better in itself, but it will not join on to the Sellers Standard, which is adopted and is in use in this country and in a good many parts of the world. The Whitworth Standard is about the same as regards pitch, and there is no reason why the Sellers and Whitworth threads should not extend their series downward to small screws—with the modification before suggested. It is absurd to make a new series extending above $\frac{1}{4}$ inch which is different from these—thus giving us two kinds of $\frac{1}{4}$-inch, $\frac{5}{16}$-inch, and $\frac{3}{8}$-inch screws, etc.

Mr. Ambrose Swasey.—I am very glad indeed that Mr. Tyler has presented this paper to the Society, for he has given a great deal of attention to this subject, and fully appreciates its importance. I think it is a subject which may well be considered by the Society, and to that end I move that the question of appointing a committee of five, for the purpose of considering the question of formulating a standard for screw threads of smaller diameters, be referred to the Council with power.

Mr. Oberlin Smith.—I second the motion.

The motion was carried.

Mr. F. H. Boyer.—I think it is due to The American Society of Mechanical Engineers that this question of the standardization of screw threads should be revised. At the first meeting of the Society some twenty-two years ago, a gentleman who is in the room brought up this question. At that time we did not have

instruments measuring $\frac{1}{10000}$ part of an inch. Every blacksmith had a lathe to turn out a tap, and had his own gauge. We have here in the room a gentleman who brought up this question at that time, and there has never been any attempt since then up to this time to revise this standard. I am heartily in favor of it. I would like to hear from the gentleman who brought forward the proposition to standardize screw threads at that first meeting, Mr. George R. Stetson, of New Bedford.

Mr. Stetson.—This is getting to be a matter of ancient history, to go back to the commencement of this Society and to consider this subject; at the same time, in my efforts to establish some standards, with the fraternity, on that work, I ran against a great many snags. With the greatest care at one time I manufactured a set of standards and standard tools, and took them to one of the largest manufacturers of bolts in the United States. He had complained of the variation of sizes. I thought I would have him on one set of tools that I had exhausted my ability in making right. Very much to my mortification, when I got there he said the proper way to do that thing was to go in and get a bolt. Well, he did so. He brought in a bolt which he had cut in his shop. It was but a very little while before I was floored. My nice tools were side-tracked. What was the matter I did not know. They were good enough at home. They would interchange at home. They were ground out finely. I happened to have brought along in my pocket a little measuring tool which was made from an accurately cut thread, so that it measured the distance in 2 inches of the threads, and I dropped that into the thread which he had brought in from his shop to test the tools by, and I found that he had been cutting that bolt with a dull die and had drawn the thread one-half of its length in 2 inches, so that he had a fractional thread to try my work on. So after you have gone to work on this matter of standardizing the tools you will have to have the committee go back to standardize the thread that is made with the tools used by the screw manufacturers. That will be where you will run against the trouble that I struck. It is a fact that in making the screws with great rapidity, if the solid die gets dull the thread is drawn and you get a fractional thread, and trouble.

Going back a little farther in ancient history, to the commencement of the war, I had considerable to do with making screws to interchange with the government standards; that was a thing

which the government was weak on at that time, and I presume is to-day—to make screws that will interchange in their gun work. It frequently happens that in the manufacture of screws they fail to fit the gauge. You will find that all through, but that is no excuse for not making matters better; only look out for the defects in the manufacture of screws.

Mr. Wilfred Lewis.—I want to say that some years ago I made an examination of the question of pitches at the instance of Mr. William Sellers, the originator of the system. In order to include all sizes he obtained from the manufacturers and users of small screws the pitches which were then in use, and handed them to me with instructions to develop a formula which would cover, if possible, not only the United States Standard sizes, but also as nearly as possible all the screw sizes which were then in current use. Unfortunately, at the time the Sellers system was inaugurated, no screws below $\frac{1}{4}$ of an inch in diameter were considered in the list of standard sizes, and when the standard formula is applied to smaller screws, the pitches indicated by it are found to be too coarse. Indeed, the pitch of the standard $\frac{1}{4}$-inch screw is generally admitted to be too coarse, and many taps and dies for this size are now made 24 threads to the inch instead of 20. So I found that the Sellers formula was not designed or adapted to cover a complete range of sizes from zero on the one hand to the largest sizes met with in practice. It covers very well all sizes above $\frac{1}{2}$ inch, but as the diameter decreases the pitches become proportionately coarser, and finally inadmissible. For example, if we make $d = 0$ in the Sellers formula $p = .24\sqrt{d + .625} - .175$, we have $p = .0146$, which is a very large pitch for so small a screw, and it is evident that in any formula of general application we must have $p = 0$ when $d = 0$.

Mr. Bond has suggested a change in the coefficient .24 making it .23 with some improvement in results, but applying this limit test to the Bond formula $p = .23\sqrt{d + .625} - .175$ we find when $d = 0$, that $p = .0064$.

This formula develops material changes in the pitches of large screws and fails utterly to meet the requirements of very small ones. In support of this statement I would refer to Table II of the paper under discussion, where the proper pitch for a screw .05 inch diameter is given as 72 threads per inch. Now, I contend that this pitch is far too coarse for so small a screw, as may readily be seen when magnified to 1 inch diameter. When so magnified

we have .05 x 72 = 3.6 threads per inch, as against 8 threads on the 1-inch standard, and the root diameter is reduced by the coarse thread to about .64 of the outside diameter, thus making the area of the root section only about .4 that of the original section. A screw proportioned in this way would be valueless as a binding screw and of doubtful utility for other purposes.

There may be good reasons for making small screws relatively coarser in pitch than large ones, but there is certainly a limit below which the number of threads per diameter should not be reduced, and I believe the standard $\frac{1}{4}$-inch bolt marks that limit at 5 threads per diameter. This makes a bolt liable to jar loose on slight provocation, and its strength is very much impaired by the coarseness of the thread. Six threads per diameter would be better for the $\frac{1}{4}$-inch size, but 5 might be tolerated as a limit for very small sizes, and from an examination of the data collected by Mr. Sellers I found 5 threads per diameter to be the actual practical limit below which very few, if any, manufacturers of small screws ventured to go. The problem which I had before me was, therefore, to retain as many as possible of the standard pitches in a formula which would agree at the same time with the average practice in very small sizes, and after many trials, I found that the expression giving the best general results could be written $p=.22\sqrt{d+.25}-.11$. This is of the same general form as the original Sellers formula, and the pitches indicated by it coincide closely with the Sellers pitches for all sizes from 6 inches down to $\frac{1}{2}$ inch or $\frac{3}{8}$ inch. It increases the number of threads on $\frac{1}{4}$-inch screws from 20 to 24 as required by modern practice, and it agrees closely with the practice of watchmakers and others using very small screws even to the limit of making $p=0$ when $d=0$.

Mr. John Riddell.—Mr. J. F. Madgett, chief inspector of the General Electric Co.'s works at Schenectady, who has had a vast amount of experience with machine screws, purchased from screw manufacturers, has given the matter a great deal of personal attention, and together we would offer the following suggestions for the consideration of the Committee which is to consider this matter.

First.—In view of the proposed change from our present standard of measurements to the metric system, would it be wise to make any change in the standards for machine screws until this matter is definitely settled, as, if the changes are made at this time and the metric system comes into effect some time in the near future, will it not be necessary to go over the whole matter of

standards to make them conform to the metric system of measurements?

Second.—We do not see the necessity of carrying the machine screw list above $\frac{1}{4}$ of an inch, as we now have the United States Standard, which starts at $\frac{1}{4}$ inch, and appears to be entirely satisfactory for every purpose.

Referring to table No. 1 of Mr. Tyler's paper, in the column under the standard of number of threads per inch, I notice that the number of threads is repeated in two instances, giving the same number of threads per inch for two different diameter numbers. Carrying out the suggestion of starting at $\frac{1}{4}$ inch, the number of threads per inch are as

Proposed by Mr. Tyler:		We would propose:	
.250	24	.250	24
.220	28	.220	26
.200	30	.200	28
.180	32	.180	30
.165	32	.165	32
.150	36	.150	36
.135	40	.135	38
.125	40	.125	40
.110	44	.110	44
.100	48	.100	48
.090	52	.090	52
.080	56	.080	56
.070	60	.070	60
.060	64	.060	64
.050	72	.050	72

This will keep each number separate and distinct, giving each one a number of threads per inch of its own.

The matter of gauges suggested by Mr. Tyler seems to cover the ground very thoroughly, as does also the limits of variations, as shown in table No. 5.

There is one other important matter which has not been mentioned in connection with machine screw standards, and that is the matter of heads, no two manufacturers making heads of the same shapes and diameters. Large consumers of screws have a great deal of trouble from this cause, and a great many attempts have been made to have the evil corrected, but without any success.

Herewith are several cuts, which will show clearly what we now get from the different manufacturers (Figs. 263-265) and what has been proposed for standard (Figs. 266-268) for two sizes; this, however, is merely a suggestion and may be of some assistance to your Committee.

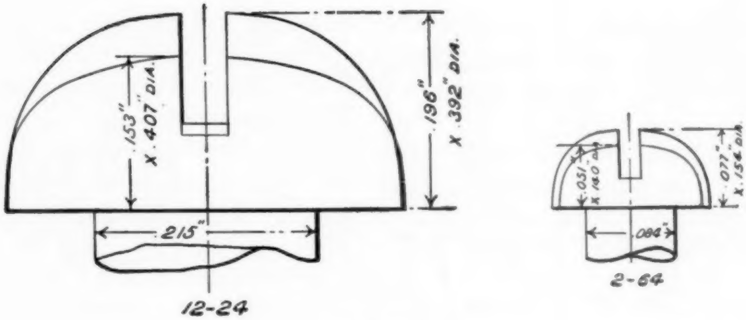


FIG. 263.

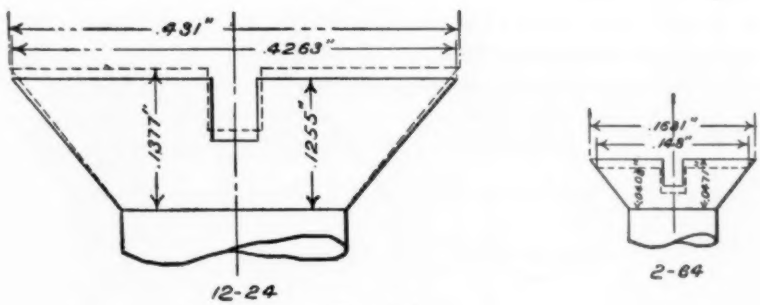


FIG. 264.

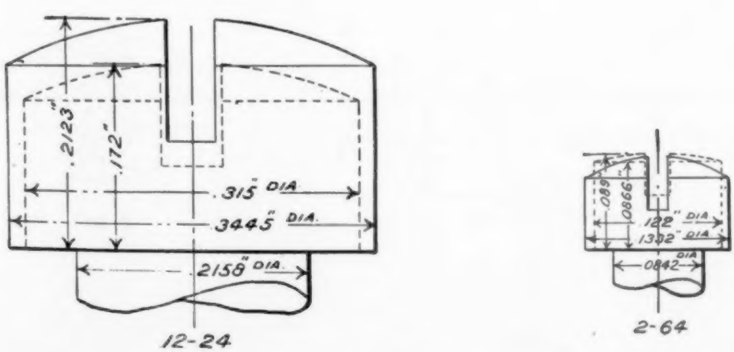


FIG. 265.

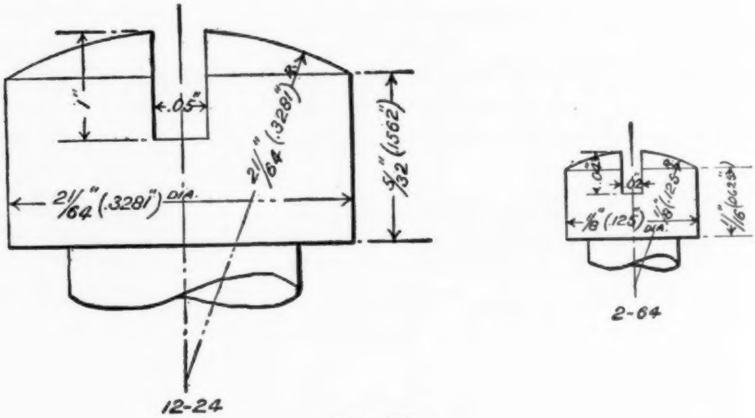


FIG. 266.

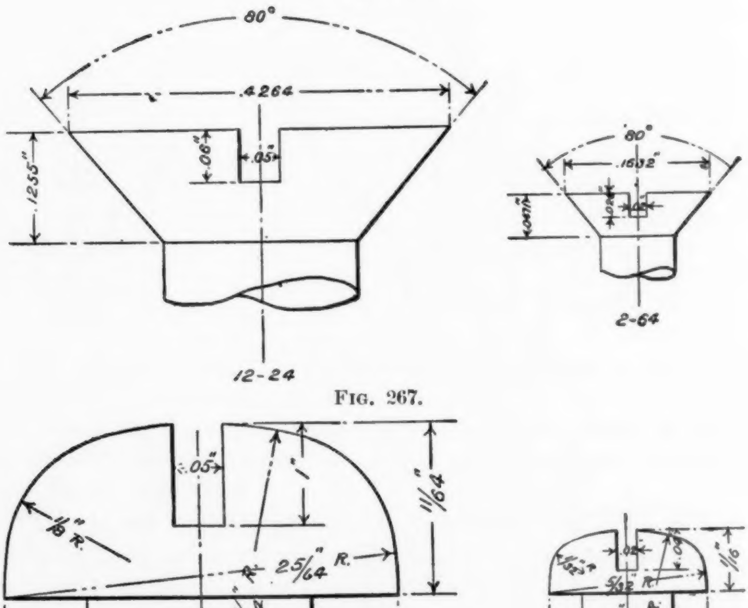


FIG. 267.

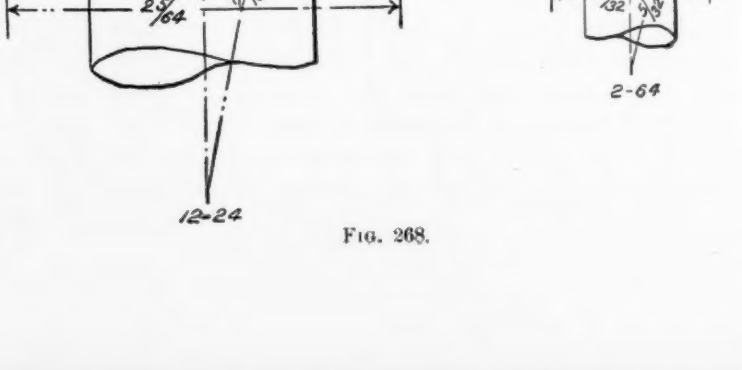


FIG. 268.

To a concern like the General Electric Co., which handles 44,235,000 screws per year, the matter of machine screw standards becomes a very annoying one under the present system, or lack of system, of manufacturing them.

*Mr. C. C. Tyler.**—The main object in presenting this paper was to develop a sufficient degree of interest in the subject to warrant the appointment of a committee to consider the standardization of small machine screw thread sizes, and the action taken by the Society is therefore most gratifying.

The adoption of the United States Standard sizes for bolts, nuts, and screws threads, for diameters $\frac{1}{4}$ inch and larger, has been so general by the progressive firms of the country engaged in mechanical engineering work that it seems desirable to limit the scope of the Committee's work to those sizes of machine screws $\frac{1}{4}$ inch and smaller in diameter. To change the present gauge sizes above $\frac{1}{4}$ inch in diameter would necessitate an expenditure which is hardly warranted, particularly if the only reason for the change is to make the pitches of these sizes conform to a new formula.

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*Author's closure, under the Rules.

No. 945.*

SPECIFICATIONS FOR STEEL FORGINGS, STEEL CASTINGS AND STEEL BOILER PLATES.

BY WILLIAM R. WEBSTER, PHILADELPHIA.
(Member of the Society.)

1. At the request of the Secretary, I am submitting as a matter of information to this Society, the specifications for Steel Castings, Forgings, and Boiler Plate of the American Section of the International Association for Testing Materials. These specifications were prepared by their Committee No. 1, and as "proposed specifications," they have been widely discussed during the past two years. At the annual meeting of the American Section, in June last, at Niagara, these specifications were adopted as their standards, but no attempt has been made to put them in general use.

2. The course which has been followed with the rail specifications will be pursued with these. The rail specifications were brought up for discussion by the "Committee on Rail" of the American Railway Engineering and Maintenance of Way Association at their annual meeting in Chicago, March, 1901, and at their annual meeting this year, were adopted with some important modifications. The next step will be to refer these modifications to Committee No. 1 of the American Section, who will report on the same at their annual meeting at Atlantic City, June 12, 13 and 14, when the modifications will no doubt be accepted. All the members of the other committees, or interested members of the other societies, who have considered these specifications, will be invited to be present, and take part in the discussion. In this way a good representative standard rail specification will be obtained.

3. With this explanation, these specifications are offered for con-

* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

sideration and discussion. In order to bring out a good discussion on each of these specifications, other members of Committee No. 1 will write short papers bearing on the most important points.

4. The subject is one of the greatest importance to all, and I know of no set of men who are more interested than our members, in securing good, sound, reliable steel castings, forgings, and boiler plates. I trust that the discussion will result in a committee being appointed on specifications, in order that the American Society of Mechanical Engineers may do its part of the work, and assert its influence in putting into final shape these specifications for general use in this country. In work of this kind one society can be of great service to another without any actual connection between them.

STANDARD SPECIFICATIONS FOR STEEL FORGINGS.

Process of Manufacture.

1. Steel for forgings may be made by the open-hearth, crucible, or Bessemer process.

Chemical Properties.

2. There will be four classes of steel forgings which shall conform to the following limits in chemical composition :

	Forgings of soft or low carbon steel.	Forgings of carbon steel not annealed.	Forgings of carbon steel, oil tempered or annealed.	Forgings of nickel steel, oil tempered or annealed.
	Per cent.	Per cent.	Per cent.	Per cent.
Phosphorus shall not exceed......	0.10	0.06	0.04	0.04
Sulphur "	0.10	0.06	0.04	0.04
Nickel "	—	—	—	3.00–4.00

Physical Properties.

Tensile Tests.

3. The minimum physical qualities required of the different sized forgings of each class shall be as follows :

Tensile Strength.	Yield point.	Elongation in 2 inches.	Contraction of area.	
Pounds per square inch.		Per cent.		SOFT STEEL OR LOW CARBON STEEL.
58,000	29,000	28	35	For solid or hollow forgings, no diameter or thickness of section to exceed 10 inches.
				CARBON STEEL NOT ANNEALED.
75,000	37,500	18	30	For solid or hollow forgings, no diameter or thickness of section to exceed 10 inches.
	Elastic limit.			CARBON STEEL ANNEALED.
80,000	40,000	22	35	For solid or hollow forgings, no diameter or thickness of section to exceed 10 inches.
75,000	37,500	23	35	For solid forgings, no diameter to exceed 20 inches or thickness of section 15 inches.
70,000	35,000	24	30	For solid forgings, over 20 inches diameter.
				CARBON STEEL, OIL TEMPERED.
90,000	55,000	20	45	For solid or hollow forgings, no diameter or thickness of section to exceed 3 inches.

Tensile strength.	Elastic Limit.	Elongation in 2 inches.	Contraction of area.	
Pounds per square inch.		Per cent.		CARBON STEEL, OIL TEMPERED.
85,000	50,000	22	45	For solid forgings of rectangular sections not exceeding 6 inches in thickness, or hollow forgings, the walls of which do not exceed 6 inches in thickness.
80,000	45,000	23	40	For solid forgings of rectangular sections not exceeding 10 inches in thickness, or hollow forgings, the walls of which do not exceed 10 inches in thickness.
				NICKEL STEEL, ANNEALED.
80,000	50,000	25	45	For solid or hollow forgings, no diameter or thickness of section to exceed 10 inches.
80,000	45,000	25	45	For solid forgings, no diameter to exceed 20 inches or thickness of section 15 inches.
80,000	45,000	24	40	For solid forgings, over 20 inches diameter.
				NICKEL STEEL, OIL TEMPERED.
95,000	65,000	21	50	For solid or hollow forgings, no diameter or thickness of section to exceed 3 inches.
90,000	60,000	22	50	For solid forgings of rectangular sections not exceeding 6 inches in thickness, or hollow forgings, the walls of which do not exceed 6 inches in thickness.
85,000	55,000	24	45	For solid forgings of rectangular sections not exceeding 10 inches in thickness, or hollow forgings, the walls of which do not exceed 10 inches in thickness.

Bending Test.

4. A specimen one inch by one-half inch (1 inch x ½ inch) shall bend cold 180 degrees without fracture on outside of bent portion, as follows:

Around a diameter of one-half inch, for forgings of soft steel.

Around a diameter of one and one-half inches, for forgings of carbon steel not annealed.

Around a diameter of one and one-half inches, for forgings of carbon steel annealed, if twenty inches in diameter or over.

Around a diameter of one inch, for forgings of carbon steel annealed, if under twenty inches diameter.

Around a diameter of one inch, for forgings of carbon steel oil-tempered.

Around a diameter of one-half inch, for forgings of nickel steel annealed.

Around a diameter of one inch for forgings of nickel steel oil-tempered.

TEST PIECES AND METHODS OF TESTING.

Test Specimen for Tensile Test.

5. The standard turned test specimen, one-half inch (½ inch) diameter and two inch (2 inch) gauged length, shall be used to determine the physical properties specified in paragraph No. 3. It is shown in the following sketch:

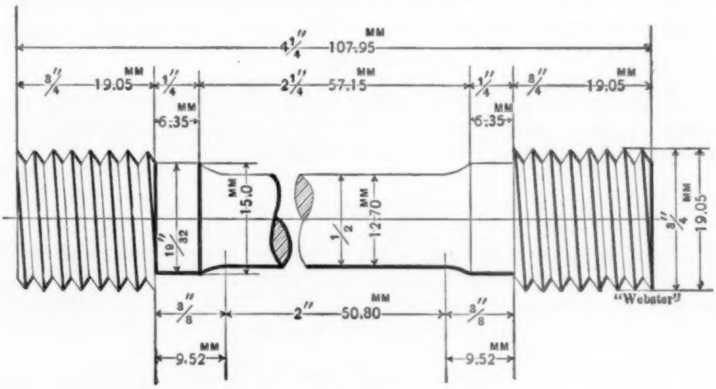


FIG. 269.

Number and Location of Tensile Specimens.

6. The number and location of test specimens to be taken from a melt, blow, or a forging, shall depend upon its character and importance, and must, therefore, be regulated by individual cases. The test specimens shall be cut cold from the forging or full-sized prolongation of same parallel to the axis of the forging, and half way between the centre and outside, the specimens to be longitudinal, *i.e.*, the length of the specimen to correspond with the direction in which the metal is most drawn out or worked. When forgings have large ends or collars, the test specimens shall be taken from a prolongation of the same diameter or section as that of the forging back of the large end or collar. In the case of hollow shafting, either forged or bored, the specimens shall be taken

within the finished section prolonged, half way between the inner and outer surface of the wall of the forging.

Test Specimen for Bending.

7. The specimen for bending test one inch by one-half inch (1 inch x ½ inch) shall be cut as specified in paragraph No. 6. The bending test may be made by pressure or by blows.

Yield Point.

8. The yield point specified in paragraph No. 3 shall be determined by the careful observation of the drop of the beam, or halt in the gauge of the testing machine.

Elastic Limit.

9. The elastic limit specified in paragraph No. 3 shall be determined by means of an extensometer, which is to be attached to the test specimen in such manner as to show the change in rate of extension under uniform rate of loading, and will be taken at that point where the proportionality changes.

Sample for Chemical Analysis.

10. Turnings from the tensile specimen, or drillings from the bending specimens or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether or not the steel is within the limits in chemical compositon specified in paragraph No. 2.

FINISH.

11. Forgings shall be free from cracks, flaws, seams or other injurious imperfections, and shall conform to dimensions shown on drawings furnished by the purchaser, and be made and finished in a workmanlike manner.

INSPECTION.

12. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

STANDARD SPECIFICATIONS FOR STEEL CASTINGS.

PROCESS OF MANUFACTURE.

1. Steel for castings may be made by the open-hearth, crucible or Bessemer process. Castings to be annealed or unannealed as specified.

CHEMICAL PROPERTIES.

Ordinary Castings.

2. Ordinary castings, those in which no physical requirements are specified, shall not contain over 0.40 per cent. of carbon, nor over 0.08 per cent. of phosphorus.

Tested Castings.

3. Castings which are subjected to physical test shall not contain over 0.05 per cent. of phosphorus, nor over 0.05 per cent. of sulphur.

PHYSICAL PROPERTIES.

Tensile Tests.

4. Tested Castings shall be of three classes: "HARD," "MEDIUM," and "SOFT." The minimum physical qualities required in each class shall be as follows:

	Hard castings.	Medium castings.	Soft castings.
Tensile strength, pounds per square inch.	85,000	70,000	60,000
Yield point, pounds per square inch	38,250	31,500	27,000
Elongation, per cent. in two inches	15	18	22
Contraction of area, per cent.	20	25	30

Drop Test.

5. A test to destruction may be substituted for the tensile test, in the case of small or unimportant castings, by selecting three castings from a lot. This test shall show the material to be ductile and free from injurious defects, and suitable for the purpose intended. A lot shall consist of all castings from the same melt or blow, annealed in the same furnace charge.

Percussive Test.

6. Large castings are to be suspended and hammered all over. No cracks, flaws, defects, nor weakness shall appear after such treatment.

Bending Test.

7. A specimen one inch by one-half inch (1 inch x ½ inch) shall bend cold around a diameter of one inch (1 inch) without fracture on outside of bent portion, through an angle of 120 degrees for "SOFT" castings, and of 90 degrees for "MEDIUM" castings.

TEST PIECES AND METHODS OF TESTING.

Test Specimen for Tensile Test.

8. The standard turned test specimen, one-half inch (½ inch) diameter and two-inch (2 inch) gauged length, shall be used to determine the physical properties specified in paragraph No. 4. It is shown in the following sketch:

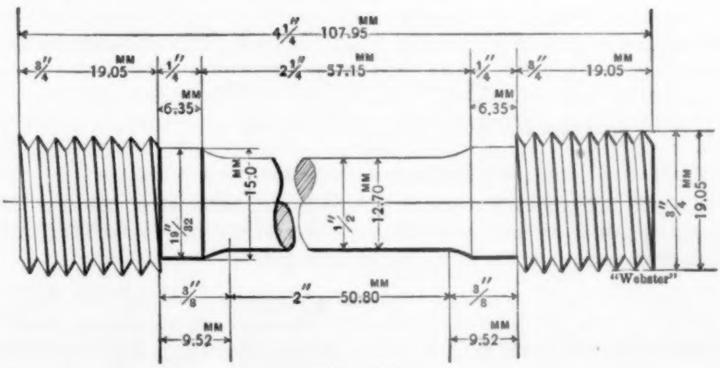


FIG. 270.

Number and Location of Tensile Specimens.

9. The number of standard test specimens shall depend upon the character and importance of the castings. A test piece shall be cut cold from a coupon to be moulded and cast on some portion of one or more castings from each melt or blow, or from the sink-heads (in case heads of sufficient size are used). The coupon or sink-head must receive the same treatment as the casting or castings, before the specimen is cut out, and before the coupon or sink-head is removed from the casting.

Test Specimen for Bending.

10. One specimen for bending test one inch by one-half inch (1 inch x ½ inch) shall be cut cold from the coupon or sink-head of the casting or castings as specified in paragraph No. 9. The bending test may be made by pressure or by blows.

Yield Point.

11. The yield point specified in paragraph No. 4 shall be determined by the careful observation of the drop of the beam or halt in the guage of the testing machine.

Sample for Chemical Analysis.

12. Turnings from the tensile specimen, drillings from the bending specimen, or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether or not the steel is within the limits in phosphorus and sulphur specified in paragraphs Nos. 2 and 3.

FINISH.

13. Castings shall be true to pattern, free from blemishes, flaws, or shrinkage cracks. Bearing surfaces shall be solid, and no porosity shall be allowed in positions where the resistance and value of the casting for the purpose intended, will be seriously affected thereby.

INSPECTION.

14. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture prior to shipment.

STANDARD SPECIFICATIONS FOR OPEN-HEARTH BOILER PLATE.

PROCESS OF MANUFACTURE.

1. Steel shall be made by the open-hearth process.

Chemical Properties.

2. There shall be three classes of open-hearth boiler plate and rivet steel, namely: FLANGE OR BOILER STEEL, FIRE BOX STEEL and EXTRA SOFT STEEL, which shall conform to the following limits in chemical composition:

	Flange or Boiler steel. Per cent.	Fire box steel. Per cent.	Extra soft steel. Per cent.
Phosphorous shall not exceed	Acid 0.06 Basic 0.04	Acid 0.04 Basic 0.03	0.04
Sulphur shall not exceed	0.05	0.04	0.04
Manganese	0.30 to 0.60	0.30 to 0.50	0.30 to 0.50

Boiler Rivet Steel.

3. Steel for boiler rivets shall be of the EXTRA SOFT class as specified in paragraphs Nos. 2 and 4.

PHYSICAL PROPERTIES.

Tensile Tests.

4. The three classes of open-hearth boiler plate and rivet steel, namely: FLANGE OR BOILER STEEL, FIRE BOX STEEL and EXTRA SOFT STEEL, shall conform to the following physical qualities :

	Flange or boiler steel.	Fire box steel.	Extra soft steel.
Tensile strength, pounds per square inch...	55,000 to 65,000	52,000 to 62,000	45,000 to 55,000
Yield point, in pounds per square inch shall not be less than........................	$\frac{1}{2}$ T. S.	$\frac{1}{2}$ T. S.	$\frac{1}{2}$ T. S.
Elongation, per cent. in eight inches shall not be less than........................	25	26	28

Modifications in elongation for thin and thick material.

5. For material less than five-sixteenth inch ($\frac{5}{16}$ inch), and more than three-fourths inch ($\frac{3}{4}$ inch) in thickness, the following modifications shall be made in the requirements for elongation :

(*a*) For each increase of one-eighth inch ($\frac{1}{8}$ inch) in thickness above three-fourths inch ($\frac{3}{4}$ inch), a deduction of one per cent. (1%) shall be made from the specified elongation.

(*b*) For each decrease of one-sixteenth inch ($\frac{1}{16}$ inch) in thickness below five-sixteenths inch ($\frac{5}{16}$ inch), a deduction of two and one-half per cent. ($2\frac{1}{2}$%) shall be made from the specified elongation.

Bending Tests.

6. The three classes of open-hearth, boiler plate and rivet steel shall conform to the following bending tests ; and for this purpose the test specimen shall be one and one-half inches ($1\frac{1}{2}$ inch) wide if possible, and for all material three-fourths inch ($\frac{3}{4}$ inch) or less in thickness the test specimen shall be of the same thickness as that of the finished material from which it is cut ; but for material more than three-fourths inch ($\frac{3}{4}$ inch) thick, the bending test specimen may be one-half inch ($\frac{1}{2}$ inch) thick :

Rivet rounds shall be tested of full size as rolled.

(*c*) Test specimens cut from the rolled material as specified above shall be subjected to a cold bending test, and also to a quenched bending test. The cold bending test shall be made on the material in the condition in which it is to be used, and prior to the quenched bending test, the specimen shall be heated to a light cherry-red as seen in the dark and quenched in water, the temperature of which is between 80 degrees and 90 degrees Fahr.

(*d*) Flange or boiler steel, fire box steel and rivet steel, both before and after quenching, shall bend cold one hundred and eighty degrees (180°) flat on itself without fracture on the outside of the bent portion.

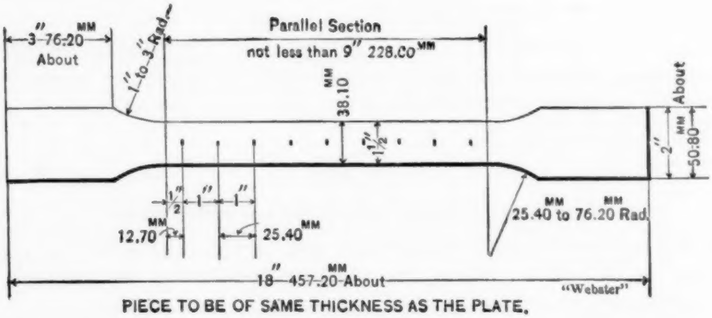
Homogeneity Tests.

7. For fire box steel a sample taken from a broken tensile test specimen shall not show any single seam or cavity more than one-fourth inch ($\frac{1}{4}$ inch) long in either of the three fractures obtained on the test for homogeneity as described below in paragraph 12.

TEST PIECES AND METHODS OF TESTING.

Test Specimen for Tensile Test.

8. The standard test specimen of eight inch (8-inch) gauged length shall be used to determine the physical properties specified in paragraphs Nos. 4 and 5. The standard shape of the test specimen for sheared plates shall be as shown by the following sketch :



PIECE TO BE OF SAME THICKNESS AS THE PLATE.

FIG. 271.

For other material the test specimen may be the same as for sheared plates, or it may be planed or turned parallel throughout its entire length and, in all cases where possible, two opposite sides of the test specimens shall be the rolled surfaces. Rivet rounds and small rolled bars shall be tested of full size as rolled.

Number of Tensile Tests.

9. One tensile test specimen will be furnished from each plate as it is rolled, and two tensile test specimens will be furnished from each melt of rivet rounds. In case any one of these develops flaws or breaks outside of the middle third of of its gauged length, it may be discarded and another test specimen substituted therefor.

Test Specimens for Bending.

10. For material three-fourths inch (¾ inch) or less in thickness, the bending test specimen shall have the natural rolled surface on two opposite sides. The bending test specimens cut from plates shall be one and one-half inches (1½ inches) wide, and for material more than three-fourths inch (¾ inch) thick the bending test specimens may be one-half inch (½ inch) thick. The sheared edges of bending test specimens may be milled or planed. The bending test specimens for rivet rounds shall be of full size as rolled. The bending test may be made by pressure or by blows.

Number of Bending Tests.

11. One cold bending specimen and one quenched bending specimen will be furnished from each plate as it is rolled. Two cold bending specimens and two quenched bending specimens will be furnished from each melt of rivet rounds. The homogeneity test for fire box steel shall be made on one of the broken tensile test specimens.

Homogeneity Tests for Fire Box Steel.

12. The homogeneity test for fire box steel is made as follows: A portion of the broken tensile test specimen is either nicked with a chisel or grooved on a machine, transversely about a sixteenth of an inch ($\frac{1}{16}$ inch) deep, in three places about two inches (2 inches) apart. The first groove should be made on one side, two inches (2 inches) from the square end of the specimen; the second, two inches (2 inches) from it on the opposite side; and the third, two inches (2 inches) from the last, and on the opposite side from it. The test specimen is then put in a vise, with the first groove about a quarter of an inch ($\frac{1}{4}$ inch) above the jaws, care being taken to hold it firmly. The projecting end of the test specimen is then broken off by means of a hammer, a number of light blows being used, and the bending being away from the groove. The specimen is broken at the other two grooves in the same way. The object of this treatment is to open and render visible to the eye any seams due to failure to weld up, or to foreign interposed matter, or cavities due to gas bubbles in the ingot. After rupture, one side of each fracture is examined, a pocket lens being used if necessary, and the length of the seams and cavities is determined.

Yield Point.

13. For the purpose of this specification, the yield point shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

Sample for Chemical Analysis.

14. In order to determine if the material conforms to the chemical limitations prescribed in paragraph No. 2 herein, analysis shall be made of drillings taken from a small test ingot. An additional check analysis may be made from a tensile specimen of each melt used on an order, other than in locomotive fire box steel. In the case of locomotive fire box steel, a check analysis may be made from the tensile specimen from each plate as rolled.

Variation in Weight.

15. The variation in cross section or weight of more than $2\frac{1}{2}$ per cent. from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

(*e*) Plates $12\frac{1}{2}$ pounds per square foot or heavier, up to 100 inches wide, when ordered to weight, shall not average more than $2\frac{1}{2}$ per cent. variation above or $2\frac{1}{2}$ per cent. below the theoretical weight. When 100 inches wide and over, 5 per cent. above or 5 per cent. below the theoretical weight.

(*f*) Plates under $12\frac{1}{2}$ pounds per square foot, when ordered to weight, shall not average a greater variation than the following:

Up to 75 inches wide, $2\frac{1}{2}$ per cent. above or $2\frac{1}{2}$ per cent. below the theoretical weight. 75 inches wide up to 100 inches wide, 5 per cent. above or 3 per cent. below the theoretical weight. When 100 inches wide and over, 10 per cent. above or 3 per cent. below the theoretical weight.

* * * * * * *

(*g*) For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

Table of Allowances for Overweight for Rectangular Plates When Ordered to Gauge.

Plates will be considered up to gauge if measuring not over $\frac{1}{100}$ inch less than the ordered gauge.

The weight of 1 cubic inch of rolled steel is assumed to be 0.2833 pound.

Plates $\frac{1}{4}$ inch and over in thickness.

Thickness of plate. Inch.	Width of plate. Up to 75 inches. Per cent.	75 to 100 inches. Per cent.	Over 100 inches. Per cent.
$\frac{1}{4}$	10	14	18
$\frac{5}{16}$	8	12	16
$\frac{3}{8}$	7	10	13
$\frac{7}{16}$	6	8	10
$\frac{1}{2}$	5	7	9
$\frac{9}{16}$	$4\frac{1}{2}$	$6\frac{1}{2}$	$8\frac{1}{2}$
$\frac{5}{8}$	4	6	8
Over $\frac{5}{8}$	$3\frac{1}{2}$	5	$6\frac{1}{2}$

Plates under $\frac{1}{4}$ inch in thicknesss.

Thickness of plate. Inch.	Width of plate. Up to 50 inches. Per cent.	50 inches and above. Per cent.
$\frac{1}{8}$ up to $\frac{5}{32}$	10	15
$\frac{5}{32}$ " $\frac{3}{16}$	$8\frac{1}{2}$	$12\frac{1}{2}$
$\frac{3}{16}$ " $\frac{1}{4}$	7	10

Finish.

16. All finished material shall be free from injurious surface defects and laminations, and must have a workmanlike finish.

Branding.

17. Every finished piece of steel shall be stamped with the melt number, and each plate, and the coupon or test specimen cut from it, shall be stamped with a separate identifying mark or number. Rivet steel may be shipped in bundles securely wired together with the melt number on a metal tag attached.

Inspection.

18. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

DISCUSSION.

Mr. H. H. Suplee.—I should like to ask Mr. Webster in his closure to state if these specifications have been presented to the International Association at either of their general conventions, or if they have been discussed only on this side of the Atlantic?

Mr. Gus. C. Henning.—The specification now presented to our

Society for discussion are two of a set of ten offered as standard international specifications for all materials having the element iron as a base, proposed by the American branch of an International Committee, appointed by the International Association for Testing Materials.*

Classification of Specifications.

In passing to a discussion of these specification in detail, I wish to state most emphatically that I am heartily in sympathy with the effort to establish Standard International Specifications, and also that I have never opposed such work in any manner whatsoever, but did everything in my power since 1895 to bring about such a result which would be of great benefit to producers and engineers alike.

But in order to be clear I must define what I consider to be a specification of which there may be three classes.

(1.) Specifications in General.

(2.) Standard Specifications.

(3.) Standard International Specifications.

1. *A Specification* is a document used in commerce which should clearly define the qualities of materials to be supplied by the producer; the tests which shall be applied for the determination of the qualities of the material produced; and the methods which shall be used to determine that all materials furnished shall possess such qualities, shape and finish as are prescribed. The terms used in such documents must be applied in accordance with their strict technical definitions as used by those most conversant with them, and the language should be of such accuracy that there can be but a single interpretation of each and every clause. A specification becomes a part of a contract and should be legally perfect and accurate. Inaccuracy of definition and diction have given endless cause for misunderstanding and lawsuits, and should be avoided.

2. *A Standard Specification* is one in which the requirements have in every case been based on the best current practice adopted

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* In view of a disposition on the part of the members of the Society to have the subject of Specifications for Forgings, etc., referred to a Special Committee, the Publication Committee have directed the omission from the Discussion of matters which do not bear directly upon the technical questions raised by the paper.

by the recognized authorities, and which has given uniformly satisfactory results when carried out.

3. *A Standard International Specification* is one which complies with the above requirements, but is also based on the best practice obtaining in all countries as enunciated by authorities in them.

The latter class is that which concerns us at this time, because the subject under discussion was inaugurated under international auspices and is proposed for international adoption. They cannot, therefore, ignore European practice, but should make full allowance therefor, and be based on the present state of the art of making steel and of the science of testing materials as enunciated by European authorities who are the recognized leaders.

These specifications are wanting in many respects; they prescribe some material which should not be used in any case, specify test-pieces and methods of testing which are unreliable and do not give accurate knowledge. Methods of inspection are practically omitted altogether.

Their worst characteristic is, however, the fact that in many points they are directly opposed to the interests of the producer, and must cause the rejection of much material which should be entirely satisfactory, and which would fill the requirements when subjected to correct tests.

The test-pieces and methods of testing prescribed are those which were in common use in this country twenty-five years ago, and I regret that European engineers have, by these specifications, been led to believe that we have learned nothing in this matter during a whole generation.

I shall now proceed to prove the above assertions which may appear too condemnatory to many engineers. While the physical properties prescribed in Paragraph 3 may be general satisfactory, there are two criticisms to offer:

First.—The various grades of steel are not sufficiently qualified to insure that one or the other will be accepted, because it is nowhere defined between which limits of strength or ductility each grade shall lie. This criticism applies to all of the specifications.

Second.—The specification of a yield point of 29,000 and minimum tenacity of 58,000 lbs. per square inch for forged steel, is so low that none but very poor steel will show such results. It will be noticed that in the case of some of these forged steels the yield

point is specified, while in others it is the elastic limit; but this matter will be taken up later.

In Paragraph 4 a specimen for bending test 1 by ½ inch is prescribed, only two dimensions being given, and hence it is permissible to interpret this clause at pleasure. As the length of a bending test specimen affects the result of a test, it is imperative to state this as well, and the omission thereof is inexcusable. It is further stated that "this specimen . . . shall bend around a diameter," and that the test may be made (Paragraph 7) by "pressure, or by blows." It is not stated that the specimen shall be bent around a bar, pin, or plug of a certain radius of curvature, but merely bent around the abstract idea of a "diameter." Now, it makes a great difference in results whether such piece of material has been bent free, or around a resisting object of definite curvature, and the latter will be a more favorable test and one which the producer should demand. Bending free does not bend the material to any definite curvature, but to any kind of irregular shape, frequently producing a sharp kink at centre. Again, it has been demonstrated that bending material by "blows" is most unreliable and has frequently caused unwarranted rupture. This procedure is again directly against the interests of the producer. In order to make a satisfactory bending test which will give reliable information, it is necessary to use a test-piece of proper shape and length, and then to bend it slowly around a resisting object of prescribed curvature. This alone will truly characterize the material and be a test fair to the producer. Machines for this purpose have long been in the market. Any other bending test should be shunned. On the continent of Europe slow bending about a pin or plunger of definite curvature is prescribed almost universally. As this method may appear to involve additional expense, I must add a few words about the cost of testing.

The testing laboratory in all works should be as profitable to the producer as every other department of the works. There is no reason why he should make tests unless the cost of same be paid by the purchaser. I would go a step further than this and advocate that all material cut from stock for the purpose of obtaining test-pieces should be charged up at contract price against the purchaser. These specifications should contain such a clause. He who then desires to know his material thoroughly will pay somewhat more for the confidence he will possess in his material

than the one who accepts it on the face value of an attested certificate of tests furnished free of charge by the producer. On the other hand, the producer will make a profit out of the testing laboratory, and can equip one of sufficient completeness to serve every purpose, and this at the cost of his customers. This would be the only just and equitable manner of providing for proper testing for commercial purposes.

In Paragraph 5 a drawing of a test-piece showing a 2-inch gauge length is given as the standard test-piece to be used. While such a test-piece is not used in any other country, it possesses nearly all the bad points which a test-piece could possibly have. It is too short; it is affected by the resistance of the threads; and the results as to strength are affected by the shoulders between thread and gauge point. In the first place, the cylindrical part should be continued at least $\frac{1}{2}$ inch beyond each gauge-mark; then this should be filleted directly to the threaded shoulders. Any such proximity of shoulders to gauge marks as shown will affect extensions and resistance, and in a manner quite indefinite, depending upon the location of the fracture. Unless fracture occurs at the precise centre of length, the extension will be many per cent. less than should be credited to the material.

In Paragraphs 8 and 9, the methods for determining "yield point" and "elastic limit" are prescribed, and these display such lack of knowledge of even the definitions and meaning of these terms that I am compelled to explain the matter in detail. According to Paragraph 8 the yield point is made to be a function of the testing machine, while in Paragraph 9 the elastic limit appears to be a function of the testing machine and of an undescribed apparatus, while they are both really functions of the material. There are three terms used in defining the elastic properties of materials, viz.: proportional limit, elastic limit, and yield point.*

The "proportional limit" is that point at which the extension ceases to be proportional to loads applied, and it is determined by measuring the extensions at regular intervals of increment of load. The precise determination of this point is dependent upon the precision of the measuring instrument.

The "elastic limit" is that load under which the material first takes permanent set and does not return to its original shape. The precise location of this point, like the proportional limit, is

* See page 30, "Martens's Handbook of Testing Materials," Wiley, New York.

dependent upon the accuracy of precision of the apparatus used in its determination, and is more or less clearly defined in different materials. It can only be determined by successive application and removal of increasing loads, and the determination of extension and set produced by same.

The "yield point" is that point at which the material shows a rapid increase of extension under increasing load. There is a very ready and accurate method of determining it by simple means, consisting of a pair of dividers on which is mounted a reading glass for those who are not gifted with the best sight. This device, which I have used in my practice for many years, is well-known. When a piece of forged steel 8 inches long is loaded to its supposed yield point of 35,000 pounds it will stretch 0.011 inch, assuming $E = 29,500,000$. When the yield point is as high as 65,000 pounds per square inch this test piece will stretch 0.0176 inch. Should the material stretch more than these amounts it is either not up to requirements, or the yield point has been passed. In order to determine the yield point the dividers are set to 8 inches, and the 8-inch gauge marks are placed on the test piece, as well as another mark 2 or 3 hundredths of an inch within one of them. The test piece is then subjected to load, while one point of the dividers is held on one of the gauge marks; as the material stretches under load the scribed lines on it will travel under the other point of the dividers, and as soon as the inner line is reached, the yield point has been passed, which will be made manifest by a sudden rapid extension of the test piece under the free point of the dividers.

It is a well-known fact that the drop of the beam of a lever testing machine depends upon the inertia of levers, and poise, the rate of loading, and last, but not least, upon the pleasure of the person manipulating the testing machine. Such manipulation has been so frequently demonstrated to be intentional that it is not necessary to say anything more about it at the present time.

The drop of the gauge in an hydraulic machine, on the other hand, depends upon the speed of loading, and the inertia and mechanism of the gauge itself. This will give reliable results only when it is operated very slowly, which is contrary to the present custom of rapid testing. In both cases, however, slip of the test piece in the holders vitiates the observations, making them unreliable and fixing the yield point at a value lower than the material should indicate; and this is again against the interests of the producer. In Emery's testing machines the drop of the

beam is so indefinite and difficult to observe that it cannot be used for the purpose stated.

The dividers, on the other hand, always permit reliable and exact determinations of yield point, and can be used at any speed of operation of the testing machine, with equal certainty.

There is, however, another method by which the yield point and other properties of materials can be determined with accuracy—by autographic apparatus, such as my "Pocket Recorder";* and this, moreover, gives a permanent record of results which, when properly made, are of the greatest practical value.

It will be seen from the above figures, however, that the elastic stretch up to the yield point of test pieces 2 inches long, will be but one-quarter of the amounts stated, viz., 0.00275 and 0.0044, which are such minute dimensions that they cannot serve practical purposes or be observed by the naked eye. The compilers of these specifications know that this minute extension of 2-inch test pieces does not produce drop of beam or lag of gauge in a manner similar to the 8-inch lengths, and hence specified the determination of what they call the elastic limit, which by the method prescribed for its determination is clearly nothing else than the yield point. The apparatus used shall show the change in rate of extension under uniform load, and elastic limit will be taken at that point where the proportionality changes. As it has been declared by such authorities as Baushinger, Martens, Tetmayer, Bach, Barba, Le Chatelier, Unwin and others that the determination of the yield point by drop of beam is unreliable, the proposition to determine it by that means should be dropped. There are two other means by which the yield point can be determined on 2-inch test pieces, viz.: by accurate measuring instruments correctly designed, or by a recording apparatus which produces a diagram showing extension up to and beyond yield point multiplied 40 times. This latter diagram will then be the same as that obtained from an 8-inch test piece with record of extension multiplied 10 times, which has been declared "sufficient for practical purposes," and it gives the conditions at yield point most clearly.†

Apparatus sufficiently accurate for determining the yield point in a rapid manner are described on page 546 "Martens's Handbook," and in paper No. 943 presented at this meeting for discussion, describing a new form of roller extensometer. I wish

* *Transactions* A. S. M. E., vol. xviii., 1897, page 823.

† Page 605, "Martens's Handbook of Testing Materials."

to point out, however, that the action of these instruments, as well as that to which Paragraph 9 refers, will be affected by any change in the rate of loading by the testing machine, which is easily affected in one operated by hydraulic pressure without being apparent to the observer, whose attention must be riveted on the extensometer. To prove that an extensometer is simplex instead of duplex, like the first two mentioned above, I will present the following facts: A simplex extensometer is one which has but one indicator actuated by one element of the test piece; the duplex, on the other hand, has two, and is actuated by two elements of the surface of a test piece on opposite sides of its axis.

Only instruments based on the latter principle are sufficiently exact to determine extensions measurable by ten thousandths inches. Absolute proof is at hand * that a simplex instrument is of no value for this purpose, and will as often give a value too low as one too high; when the bar begins to stretch first on that side to which the instrument is attached, a yield point which is too low will be given. This is again against the interest of the producer who is trying to guarantee minimum values. Now, an apparatus which does not read accurately to $\frac{1}{10000}$ inch can hardly be used for the determination of differences of elongation of 0.00275 and 0.0044=0.00165 between highest and lowest yield points of 2-inch test pieces. If the stretch on one side of bar is greater than that on the other by $\frac{5}{10000}$ inch, as is frequently the case, then such apparatus will give incorrect determinations. An apparatus like that used at the Bethlehem Steel Works, being simplex, with the roller $1\frac{1}{4}$ inch away from the centre of the test piece, will give a reading of $\frac{3}{10000}$ inch, when the $\frac{1}{2}$-inch test piece elongates only $\frac{1}{10000}$ inch more on one side than on the other. Moreover, as the roller of this extensometer rolls between two plates instead of revolving on centres as it should, its axis will again be shifted one-half the amount of extension of the test piece, thereby adding another error which still further invalidates the observations. Yielding generally begins at shoulders,† and the nearer these are to the gauge marks the sooner will the apparent (but erroneous) yield point be indicated by the apparatus. In the case of 2-inch test pieces in which the shoulders are but $\frac{1}{8}$ inch from gauge marks, this will again indicate a lower yield point, to the detriment of the producer.

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* Pages 90–94, "Martens's Handbook of Testing Materials."

† See pages 90 *et seq.* "Martens's Handbook of Testing Materials."

There is another point, however, in which this 2-inch test piece notoriously fails to give correct and reliable information about the materials, viz.: extension after rupture. This again is to the detriment of the producer.* "Under the practically permissible assumption that deformations are symmetrical about the point of rupture there is one method of procedure which gives accurate values of extensibilty of materials under all conditions."† If the location of fracture is not at the centre of the 2-inch test piece, then the error will be over 4 per cent., and may reach 8 or 9 per cent. The only proper way of measuring extensions is to divide the gauge length into 20 parts, each part in an 8-inch test piece being 0.4 inch long; 1-inch divisions are much too large and will in no case answer the purpose. If the fracture is located at the centre, the extension may be measured directly. If it occurs away from this point, then the extension of an equal number of parts symmetrically located either side of the fracture is measured, and to this amount must be added twice the extension of a number of divisions on the long end of the test piece immediately adjoining those already measured, equal to $\frac{1}{2}$ of 20, less the number already measured. Thus in case the extension of 3 divisions either side of the fracture is measurable, then twice the extension of the adjoining 7 divisions is to be added to give the total extension of the gauge length. If the fracture should occur at a gauge mark, then the correct extension will be equal to twice the extension of 10 divisions nearest the point of fracture, and not to the extension measured between gauge marks.

When this is not done, the short end of the test piece having stretched less than the normal amount, the results obtained will invariably be against the interests of the producer. On a 2-inch test piece this method cannot be used, and eccentric locations always give too small an extension, which is against the interest of the producer.

I think that I have now clearly shown that a 2-inch test piece is wrong from every point of view, and that one more injurious to the interest of the producer could not well have been selected. There is but one plausible reason which might make a short test piece seem desirable, viz.: that it can be more readily cut from a forging and cause less waste and cost less.

If it be borne in mind that the purchaser should and will pay

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* See page 108, *ibid.*

† See page 111, *ibid.*

for all testing in the end, whether he knows it or not, the manufacturer should always leave enough stock to provide for test pieces of the standard instructional length of 8 inches, because it would be entirely to his own interests from every point of view.

Moreover, as standard specifications do not refer to specialties, but to the great bulk of material ordered in large masses and quantities, a few extra pieces of greater length, paid for by the purchaser, will satisfy all interests and not materially increase the cost of production. Shafts, cylinders, anchors, piston-rods, ship-forgings, frames, etc., could all be so forged as to provide proper crop-ends for 8-inch test pieces in a simple manner. Wheel tires and the like should, of course, be classed as specialties and treated as such.

In Europe 8 inches (200 per cent.) has been adopted as the standard length, and no one on the continent any longer thinks of measuring extension except by the method of proportional parts. This method cannot, however, be used on 2-inch test pieces. None of these points have been provided for in these specifications, and the best practice abroad has been entirely ignored.

All of these criticisms apply to the specifications for cast steel as well, and I shall therefore not repeat them in reviewing the latter.

Having shown that the first part of these specifications is very loosely drawn and can be misinterpreted, that they fail to take cognizance of the present state of the science of testing materials, and that they ignore common practice in other countries, I shall take up the subject of inspection.

Paragraph 12 says that "the inspector representing the purchaser shall have all reasonable facilities afforded him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications." May I ask how many different opinions exist as to what might be called "reasonable facilities"? Moreover, Paragraph 12 distinctly states that these facilities shall be afforded to satisfy the manufacturer that the finished material is furnished in accordance with these specifications.

This clause should read: "The manufacturer shall at all times furnish promptly to the purchaser or his representative all facilities necessary to test and inspect every part of all the material produced under these specifications." Furthermore, it should be specified that the inspector shall have the right to affix his private

mark to the material during any stages of the process of manufacture; that all material shall be turned over for surface inspection on both sides in all cases; that no material shall be shipped until the acceptance mark shall have been affixed thereto.

Provision should also be made for daylight inspection, for in spite of many statements to the contrary, no person can readily detect seams, cold-shuts and checks by use of artificial light with its many vagaries, variations, and shadows.

These matters are all provided for and prescribed on the continent of Europe, and when not, are carried out as a matter of common routine.

I could enumerate many other points which experience has taught me to be essential—not for the purpose of embarrassing the producer by any means—but merely to exclude any accidentally defective material which may cause very grave consequences. It is hardly necessary for me to mention such accidents as the Consolidated Gas Tank Collapse in 1898, in New York, with its great loss of life and heavy damage, the result of the inspector's failure to find a cold-shut in one plate. There is no time now to mention such matters. Unless such clauses be included in these specifications they will never be adopted as international standards.

There is another point which I should here mention, before briefly reviewing the specifications for steel castings: that is, that the processes by which steel is made are rigidly prescribed, while this might wisely be omitted.

The effect of this will be to discourage the development of new processes, excluding all electro-metallurgical methods, which are bound to be heard from at no distant date. If the other conditions of these specifications are met, there need be no stipulation as to the method of producing the steel. That will take care of itself.

Under "chemical properties," in Paragraphs 2 and 3, it is stated that castings which shall not be tested may have $\frac{6}{10}$ more phosphorus than those which are to be checked; again, in the former sulphur is not prescribed, while in the latter it is. Therefore such material which shall not be examined for quality may contain more injurious components than those which will be carefully tested; this seems an anomaly to me.

May I ask why the term "chemical properties" is used in this connection, when "chemical composition" is alone referred to? These terms are sufficiently distinct not to be misapplied or

confounded in standard specifications, and such loose use of words in a case like this is hardly justifiable or permissible, but is characteristic of the general lack of precision of these specifications. The terms " drop " and " percussive test " are also used in an unwarranted manner, and are not those commonly applied to the tests referred to, but relate to other well-known tests which are clearly defined technically. The tests specified should be called the " breaking down " and " hammer tests," which are the correct terms and can hardly be misunderstood. Another instance of careless diction, the last to which I wish to refer, although there are many others, is found in Paragraph 8, in which it is prescribed that the test piece " may be turned parallel throughout its entire length." This probably means that the test piece may be turned " truly cylindrical," because that is what it should be.

Again Paragraph 8 prescribes a 2-inch test piece for castings, and while all that I have said heretofore applies in this case, there is one reason which can be urged against its adoption for tests of cast steel. There is no difficulty whatever in producing with a casting, however large or small, a test piece 16 inches long gated from it without change of pattern, and cast at the same time. Such coupon would be a true sample of the steel and could be removed after annealing.

The provision that the test piece may be cut from the sinkhead is very objectionable because of the possibility of segregation, and of slag and dirt being in it, and because such would produce results against the interest of the producer.

Boiler Plate and Rivet Steel.

As most of the above criticisms also apply to the specifications on boiler plate and rivet steel, I shall not repeat them, but merely call attention to the shape of test piece as given in paragraph 8, as it does not conform to any standard shape nor comply with our knowledge of the necessary requirements for obtaining correct results.

I must again refer to Fig. 107, "Martens's Handbook of Testing Materials," etc., which shows the proper proportions and dimensions which alone will always give reliable and comparable results.

It would lead too far and occupy too much time to take up every point in these specifications which may be justly criticised, and I shall therefore abstain from further comment, hoping that what

I have presented will result in a revision which will produce specifications entirely satisfactory to the producers, and creditable to American engineers from every point of view.

Prof. Gaetano Lanza.—I suppose every one will admit that in all cases where it is feasible, it is much better (instead of using the small test piece) that we should use the standard test piece, on which a gauged length of 8 inches can be employed. While the difficulties which would present themselves in this regard, in the case of steel forgings, may be great, as in securing a test piece to show the qualities of a certain portion of the forging about which we wish information, it is impossible for me to see how any such difficulties can be at all insuperable in the case of steel castings; and it would seem very desirable and important that, in the case of steel castings, instead of using the short test piece, on which we can measure only on a gauged length of 2 inches, the standard specimen, on which we measure on a gauged length of 8 inches, should be adopted.

Any one who has had to do with steel castings knows that one of their greatest defects is their lack of homogeneity, and their flaws. Any investigation, therefore, of their strength should also seek to ascertain how uniform the material is and how many flaws exist. I should therefore hope that some time we might adopt, instead of the small test piece, in the case of steel castings, the longer one.

I have only one small criticism to make in regard to the longer test piece, and that refers to all kinds of work; the length on which we measure should, of course, be 8 inches. In the specification, which is also that of the International Society, as well as that of the American Section, it is specified that the distance between the shoulders shall be at least 9 inches. If any one adheres to that minimum length between the shoulders he is only leaving ½ an inch on each side of the gauged length before the section increases; and this is liable to interfere with the accuracy of some of the results. It seems to me that there should be at least 2 inches on each side of the 8, making 12 inches, before an increase of section occurs.

Mr. S. M. Vauclain.—These specifications are the result of a great deal of patient work by the Committee. In their present form they are too cumbersome for practical use. What is really required is to sub-divide them so that they may be thoroughly digested and put in shape for use. There may be some points in the specifications which might be modified to advantage. I there-

fore ask that this Society appoint a Committee on Specifications, as has been suggested, believing that the result of its work would be of great assistance towards "Standard Specifications."

Mr. Francis B. Allen.—Relative to the proposed specifications for steel boiler plate and steel castings, one cannot look even casually at the report as presented by Mr. Webster and his associates on the Committee, without being impressed with the care and attention they have exercised in the examination of authorities on this subject, and preparation of data in such shape as to make the record of those authorities of easy reference.

The subject, in my judgment, is one of the most important which could engage the attention of this Society, for, while the question is of great professional and commercial importance, it is even more important on the score of humanity; for it has to do with the protection of life and limb by establishing standards for high-grade material in boiler construction and attachments whereby not only can life be made safer, but a responsibility be established for those who fail to provide the best material under conditions for which it is evident that the best is demanded.

The demand is for higher steam pressures on boilers, yet in cases where the purchaser is willing to pay for the best and safest material for the purposes for which they are to be used, there is no absolute guarantee in many cases that it can be obtained. In other words, the purchaser will get what he pays for. If manufacturers of boiler tubes, steam pipes and steam fittings were required to legibly stamp their product, as the manufacturers of boiler plates do, the protection of their own interests would be an incentive to produce the best instead of the cheapest.

It is a practical question of some importance: If we build a high-pressure boiler, parts of which are subject to test and are demonstrated to be of the best steel plates and workmanship obtainable, and then use steel tubes, steel pipes, steel castings, and steel fittings attached to it, of unstamped and absolutely unknown qualities, where all parts are to be subject to the same high pressure, are we not guilty of a very reprehensible act—and yet is not this being done every day? By all means let us favor standard specifications as the most practical way to secure the best materials and best workmanship, and provide means of identification for all the parts, so that not only may we be able to intelligently select the best and thereby make the whole boiler structure uniformly safe, but also where any detail is not up to the trade representation

credited to an article of that quality, we may know to whom legitimately to attribute the fault.

I therefore hope that this important subject may be continued to a future meeting, for it is more important that it should be settled right than at this time; also, we may show a creditable appreciation on our part for the excellent work of the Committee.

*Mr. Webster.**—Replying to Mr. Suplee I would say that the specifications have been reported to M. Riepel, Chairman of the International Committee. I received a reply from him stating that he was very much pleased with the way in which we have carried on our work, and that he would send a circular to the members of the International Committee in other countries requesting them to carry out their work on similar lines.

In presenting the specifications for discussion, attention was called to the views expressed at the recent meeting of the American Institute of Mining Engineers in Philadelphia on the matter of elastic limit and yield point. It was claimed that it was necessary to take measurements to the $\frac{1}{10000}$ of an inch to accurately determine the elastic limit. On the other hand, it was stated that in ordinary commercial testing the yield point was taken by the drop of the beam, notwithstanding that it had been previously shown, by carefully conducted series of tests that the test piece had sometimes elongated over $\frac{2}{10}$ of an inch in 8 inches at the time the beam dropped. These may be taken as the two extremes and have caused no end of discussion and confusion. It is time we arrived at some definite conclusion regarding this important matter, and for consideration the following is quoted from Mr. Theodore Cooper's specifications for 1901:

"For the purpose of these specifications, the elastic limit will be considered the least strain producing a visible permanent elongation in a length of 8 inches, as shown by scribe marks of a pair of finely pointed dividers.

"If the yield point or drop of the beam can be calibrated for any machine and its speed to represent the elastic limit within 5 per cent., it may be used for general cases. Test reports must state by which method the elastic limit was taken."

This has not been referred to by Mr. Henning, although it fully covers the points he raised.

The members of Committee No. 1 of the American Section are perfectly familiar with what has been done in other countries. In

* Author's closure, under the Rules.

their preliminary work they considered all the points which have been referred to by Mr. Henning, and many others, and decided that as these specifications were to be representative American specifications, they would confine their work to the best American practice. This course was followed. We have nothing to do with European methods not in use here, and the other countries can look out for their own methods. In the final International Specifications each country's methods and specifications will receive due consideration.

As to the much-despised 2-inch tension test piece, as well as the bending test piece and conditions for making this test, referred to by Mr. Henning, they are the same in all respects as the standards of our Navy; and if his remarks are referred to Admiral Melville, sufficient reasons will, no doubt, be produced to prove that good material has been and will be obtained with these forms of test pieces and methods of testing.

No. 946.*

A TECHNICAL INDEX AND FILE.

BY R. H. SOULE, NEW YORK.

(Member of the Society.)

1. THIS system is a new combination of old elements, the card index and file boxes; in developing it the aim has been to secure compactness with facility for quick and ready reference, and to avoid the use of scissors and paste pot. The index card chosen as being most convenient is a medium heavy white card, approximately 3 inches by 5 inches (actually $7\frac{1}{2}$ by $12\frac{1}{2}$ centimetres), ruled with horizontal blue lines, and punched near the lower edge; in the Library Bureau catalogue this is classified as their 33 *r* white card.

2. The file boxes are of three different sizes, the inside dimensions being as follows: small size, 7 inches by 10 inches by 3 inches; medium size, $9\frac{1}{2}$ inches by $12\frac{3}{4}$ inches by 3 inches; large size, $11\frac{1}{2}$ inches by $16\frac{1}{2}$ inches by 3 inches. They are all similar to pamphlet cases in general make-up, and open both at one side and one edge, the two hinged covers of each box being fastened together by a simple catch, which is opened by pressure of the thumb. These file boxes are not to be found in stock, but can be made by any manufacturing stationer. The small size box takes pamphlets, trade catalogues, etc., of the 6 inches by 9 inches standard; the medium size box takes publications of approximately letter size,

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* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For further references on this subject see *Transactions* as follows:

Vol. xvi., p. 610: "Topical Discussions."

Vol. vi., p. 863: "Topical Discussions."

Vol. xiv., p. 780: "A General Engineering Classification and Index," William L. Chase.

Vol. xxii., p. 745: "A Method of Filing and Indexing Engineering Literature, Notes, etc.," George H. Marr.

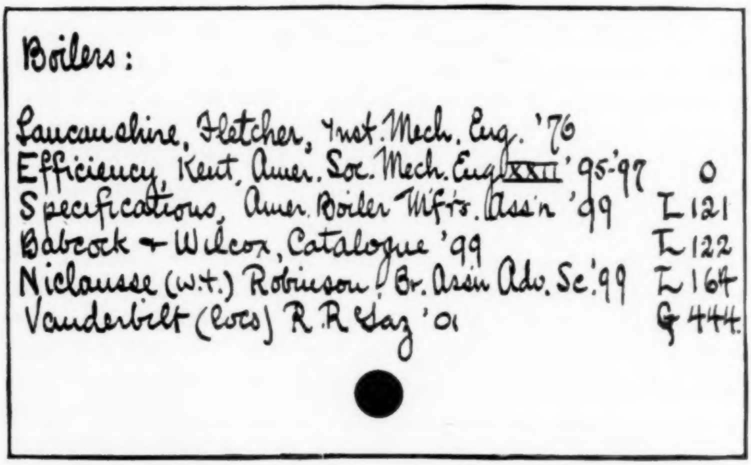
including both trade catalogues, technical papers, etc.; the large size box takes the larger technical papers; blue prints may be taken in either size box to which they will conveniently fold. The three sizes of file boxes are arbitrarily designated as *P*, *L*, and *G* (pamphlet, letter, and gazette), and each box bears on its back its appropriate designating letter.

3. All pamphlets, technical papers, etc., received, are carefully looked through, and each contained item or article which is considered worthy of being indexed is checked; the covers and advertising sheets are then stripped off, and the reading matter is cut up into single sheets, by running a paper cutter through the binding edge; those sheets which do not bear a check mark on either side are taken out and discarded; those sheets which do bear one or more check marks on either side are then bound together by metallic binders, after which the proper file number is placed in the upper right-hand corner.

4. Each size of file box has its own series of file numbers running from 1 up, and each enclosure prepared for filing (as above described) is marked with both its proper file letter and number, the first of each series being marked *P* 1, *L* 1, and *G* 1, each subsequent enclosure bears the next consecutive file number to the last one previously used in its series. In assigning the enclosures to the file boxes size alone determines; no classification by subject is attempted, that being taken care of by the card index; no vacant numbers or spaces are left, and each series is filled up solid.

5. After the file enclosures are prepared and given their file numbers, the checked items and articles are indexed, by making the proper entries, by subject, on the index cards. The general subject is entered at the top of the card, nothing else being put on that line; six additional lines (seven in an extreme case) are available below, and these are used for consecutive references to the general subject, after which additional cards are used. The index references to enclosures in the file give the name of the technical paper, in abbreviated form, and the year of publication; it has been found to be unnecessary to give the month and day, they can be ascertained by reference to the file itself, if needed. The index also contains references to sources of information outside of the file; these are obtained by going through the files of technical papers not subscribed to, the transactions of technical societies of which the writer is not a member, and certain other

technical literature, all of which may be found in the library of the American Society of Mechanical Engineers. In making the index entries of these references, it is necessary to be specific as to the source of information, the volume, page, date, etc.; instead of the file number, which in ordinary file references appears in the right hand margin of the card, a zero is used, indicating that the reference cannot be found in the file, but must be sought in


Boilers:

Lancashire, Fletcher, Inst. Mech. Eng. '76	
Efficiency, Kent, Amer. Soc. Mech. Eng. XXII '95-'97	0
Specifications, Amer. Boiler Mfrs. Ass'n '99	L 121
Babcock + Wilcox, Catalogue '99	L 122
Niclausse (w.t.) Robinson, Br. Ass'n Adv. Sc. '99	L 164
Vanderbilt (locs) R. R. Gaz. '01	G 444

FIG. 272.

an outside source of information. Similarly, a few references to books in the writer's library are given; this is done only when a book contains some valuable information which is not covered by its title, as for instance, "Tools, power required to drive" (see Flather's "Dynamometers"). In this case, although the book is on the subject of Dynamometers, an entire chapter of 73 pp. is devoted to the subject of the power required to drive machines, and contains tabulated statements of great scope and value.

6. Typical index cards, illustrating the different classes of references, are shown in Figs. 272–274.

7. The writer's index and file were begun about two and a half years ago. During this period the accumulation of index cards and references has been as follows:

No. of Index Cards.	No. of References on each card.	Total No. of References.
105	1	105
68	2	136
34	3	102
26	4	104
22	5	110
419	6	2514
12	7	84
686		3155

Locomotives, Details & Infm:

Lead for locos., Quereau Wn Ry Club '97 P302
Crosshead, Articulated N+W. Am. Eng'r '97. L 210
Elec. B+O. Dyn. Tests, Eng. News, Mar 5th '96. O
Tenders, Weights " " June 9th '98 O
Link Motions, 4 Types, Loco Eng'rg. '01 L 211
Main Rod. P.R.R. Cl. E.2. R.R. Gaz '01 G 461

FIG. 273.

Tools:

Hydraulic, Tweddell Inst. Mech. Eng. '72 '74 '78 O
Machine, Speeds, Southwark Fdy. Old Note Bk '74 O
Flanging Press, Schen. Loco. Wks. R.R. Gaz '97 G 455
Blacksmith, Comm. Rep. Mast Blacksmith Ass. '99 L 42
Power Req. to Drive, see Flathers "Dynamometers" '00 O
Rolls, Bending N.Y.C. Hilles & Jones '01 G 26.

FIG. 274.

This shows an average of 4.6 references per card, and substantiates (for the index) the claims of compactness and facility of quick and ready reference; the more references per card the fewer cards to be provided and handled, the less space occupied, and the more cards and references consulted in a given time. Six references are considered as constituting a full card, but occasionally a seventh reference is added, if it closely relates to the

FIG. 275.

sixth. Of the total of 3,155 references, 2,269, or 72 per cent., are to enclosures contained in the file, and 886, or 28 per cent., are to outside sources.

8. The accumulation of references under individual subjects will, of course, be influenced largely by the particular field in which the person developing the index and file is working; the writer's specialty being railway mechanical engineering, the number of references accumulated under 15 principal subjects (out of a total of 271 subjects) has been as follows:

Subject.	No. of References.
Boilers	125
Brakes	70
Cars	233
Coal and coaling	65
Cranes	43
Electricity	51
Engines	79
Locomotive diagrams	198
Locomotive details and inf'm'n	314
Power plants	66
Shop diagrams	128
Shop notes and inf'm'n	55
Tools	43
Train resistance	38
Trucks	45

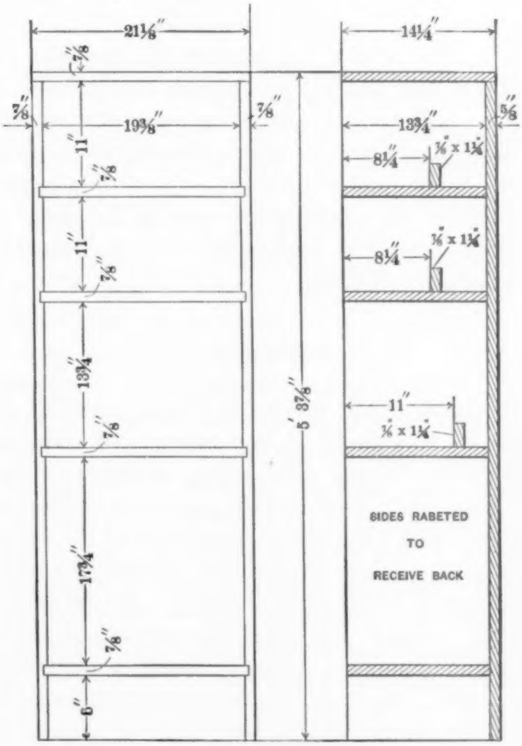


FIG. 276.

9. The index cards are kept in a four-drawer case of Library Bureau make, as shown in Fig. 275. Buff bristol guides are in-

serted between the white cards to show the alphabetical subdivisions by first and second letters.

The original outfit of file boxes (since duplicated) included 12 small size, or *P* boxes, 6 medium size, or *L* boxes, and 6 large size, or *G* boxes. These 24 file boxes are kept in a case, as shown by Figs. 275 and 276.

Each file box is provided with a leather pull tag, as shown by Fig. 275, and, when filled, is marked with the file numbers of its first and last enclosures, thus: *P* 1—*P* 30.

10. It so happens that the amount of storage space originally provided in each size of file boxes (12 *P* boxes, 6 *L* boxes, and 6 *G* boxes) was about right, each series being now completely filled with enclosures, two additional boxes of the *P* size being also filled, however. As previously stated, a second set of file boxes with file case, exactly like that shown in Figs. 275 and 276, has been provided and is now in use. In support of the claim that the file (as distinct from the index) is compact and affords facility for quick and ready reference, it should be noted that it requires only about 11 cubic feet of space to store enclosures containing 2,269 references (the remaining 886 references, out of a total of 3,155, referring to sources of information outside the file). Moreover, any one of these reference enclosures can be located and withdrawn in a minimum of time.

DISCUSSION.

Mr. H. P. Quick.—The writer has been working on the lines of the author of this paper in the manner of filing current engineering literature of the same class, namely: "Railway Mechanical Engineering", and also of general engineering information, and begs to submit not only a discussion of the author's paper, but also some observations in the line of indexing and filing not touched upon, but of value to an engineer. In general, the author of the paper has in use a very practical system and, as he says, one adapted to ready reference in daily work, provided he has the catalogue adjunct. In the treatment of engineering periodicals it resembles very closely the writer's method, which has been in use several years; but in the manner of filing it differs somewhat, and it is along this line only that the details of the author's method would be criticized.

For the catalogue instead of a 3 by 5-inch card, the better size

would be 4 by 6 inches, ruled similarly, because it will contain a greater amount of information on a card, and further, a 4 by 6-inch card is more suitable for use in recording general engineering data, tabulated information, synopses of subjects, outlines of lectures, reports, etc., and yet is within the limits of a pocket card or removable leaf note book, and all information can thus be kept in the same card index; for it is not likely that the engineer's files, or his references to articles not possessed or on file, will be all the information filed by him relating to any subject.

The author is unwise in having his system so arranged that he has to depend entirely on his card index to know what he has and where it is. Unless his card or book index is kept up to date, he surely could not go to his boxes lettered P, L, and G, etc., and find what he is looking for. The writer prefers a subject classification on the boxes and one size of box, and that a compact one, for the general run of engineering publications, and for any one starting a system, the size $8\frac{1}{2}$ by $10\frac{1}{2}$ inches will contain everything published, either laid flat, or, as in the case of *Engineering News, Scientific American*, etc., folded once with very little trimming, unless it is some abnormally large catalogue with heavy board covers coming under the class of books rather than pamphlets or magazine articles. These boxes should not be as thick as 3 inches, rather $1\frac{1}{4}$ or $1\frac{1}{2}$ inches, and perhaps more like the ordinary pasteboard box in which glass photographic plates are packed, and which can be had at a very low rate from a photographer. A box should be labelled with the subject matter contained therein, and may in addition be lettered and numbered. The small thickness, of course, requires a greater subdivision of subjects, and this is an advantage, because it reduces the weight to be handled, the amount of irrelevant matter to be looked over in case one is not using a card index, and in searching for hidden matter which a card index might not reveal. Engineering matter should not be separated by reason of difference in size but by difference in subject. A distinction will have to be made, however, for office letters, catalogues, mounted photos, specifications, blue prints, patents, reports of the nature of firm, company, or personal business, and somewhat different methods of filing, as are preferred and have been tried with success. They are first to use drawers of the sectional dimensions, about 12 by 14 inches, arranged in convenient cases about 30 inches deep, and height and width to suit the size of drawer. These to contain

numbered, lettered, or labelled manila leaf compartments, each of the latter containing all the matter pertaining to a job, case, consultation, or subject, the leaves being adjustable as to space between; second, if one has the space for the extra bulk and wishes to pay more for his files in order to keep them more free from injury and liability to misplacement, there are to be had the standard letter boxes sold by all stationers, size inside about 11 by $11\frac{3}{4}$ by $2\frac{5}{8}$ inches and otherwise, such as the author of the regular paper describes containing manila paper compartments. These files if placed on shelves should be labelled on the back with subject, and on the inside of end flap with subdivisions. These boxes, however, are clumsy to handle and very heavy if filled solid with heavy paper matter, but make a serviceable file. They can also be arranged in drawers so that their weights would not have to be lifted, and in this case the subjects and subdivisions are on the lid.

All the filing systems discussed depend on the disruption of engineering periodicals. This is the author's practice and the writer's also with but slight differences.

All periodicals and society publications are stripped of advertisements, which are destroyed, as they are largely repetitive from number to number; but it is not the writer's practice to destroy the portion of periodicals containing technical matter, nor to cut out any pertaining to other branches of engineering. These are retained under the original cover and filed in order in a convenient place for reference in case of need. In this connection all periodicals, indexes to volumes, and important articles in back numbers, should be kept together in file boxes in succession, and these in themselves form most valuable lists to consult for articles on any subject, if not found in the filing boxes or on card indexes. Engineers may sometimes forget that there are many irregular papers, and matters as well as serial ones which are proper for filing under any subject in an engineer's filing system. The complete list might be as follows, say for the subject:

Engines.

Engineering periodicals—articles.
Popular magazines—articles.
Advertisements with cuts.
Lists of firms manufacturing engines.
List of books and pamphlet book-fliers.

Society publications about.
Trade catalogues on.
Drawings of.
Photographs of.
Government departmental reports on.

As the matter accumulates the subject of engines should be divided and one or more files allowed for each type, viz.: marine, stationary land, locomotive, automobile, pumping, electric power station, etc., and further into steam, gas, air, oil, electric, heat, hydraulic, rotary, turbine, etc.

The attention of all publishers should be called to the certain conveniences which can with little expense be arranged in their publications for engineers seeking to file their engineering matter in the manner described at this time. They could greatly assist in making their publications useful, if not ornamental.

First.—In the matter of uniformity in size, which is not of very great importance, but would simplify the matter of filing.

Second.—Important articles, if not all articles, should be arranged to begin on the left-hand page of a leaf and end on the right-hand page, or blank pages should be left so that when an article is removed, no portion of any other article will go with it. It is not practiced to-day by design in any publication, but occasionally by accident it happens so. These blank pages or parts of pages could be used for advertisements in the same line as the subject-matter of the article, or as in the case of some of the larger sheets, like the *Engineering News*, short items of passing interest—miscellaneous notes, reviews, current prices, bids, work in progress, etc., could be used to fill in so that no important article would overlap, so to speak, another one, rendering the loss of a portion necessary.

Third.—All pages of a periodical should have the date of publication, name of magazine and page number at the top of each page, so that the user would not have to write the references on each article taken out.

Fourth.—Volume indexes should be more definite as to dates, and references to number should be explained.

Fifth.—Avoid by all means the scattering of illustrations on pages containing an article to which they do not refer, as many publications are now guilty of doing. This is particularly annoying.

The day has passed when the working engineer can have all his literature bound up as it comes and set on shelves convenient for inspection, as is done in libraries. The great mass of periodicals remain unbound, and, after the first perusal are removed to a dusty pile, from which there is neither the inclination nor the time to remove them for study of any subject.

Publishers will increase their sales if they will rearrange their periodical missives, so that all irrelevant matter can be easily removed and the remainder severed into complete units with title, author, date, and important details looked after.

Mr. Gardner T. Voorhees.—Any way that the engineer can arrange his data and references so that he may quickly and readily get at them will add not only to his comfort, but also to his efficiency.

Mr. Soule's paper is of interest as showing a very simple and practical way of filing and accumulating engineering data. We often read the account of some piece of apparatus in one of the scientific papers, and when we again wish to find it for reference, we discover that the paper which contained it has been loaned, lost, or forgotten. We know that the desired information exists, but we cannot find it.

The *Engineering Magazine* has appreciated the value of clippings from magazines, so that it makes a special point of publishing a set of references to subjects which have appeared in most of the scientific papers. It stands ready to supply these clippings from any paper at a low cost.

When I read the advance copy of Mr. Soule's paper it occurred to me that its discussion would give me a good opportunity to advance a pet scheme of mine in a somewhat similar line. We get trade catalogues in all sizes, shapes, and thicknesses. Some are works of art, some tell us things, and some do not. However they are all valuable, because a man never knows when he may want some information regarding some particular thing described in them. Consequently we get filing cases, boxes, etc., and set about indexing them as well as we can, with the result that catalogues of some one subject which should all go together in the file are so small that they get lost between the pages of others, and some are too large to get into the filing boxes at all. The result of all this is that often when we want a catalogue it has been lost. The more this Society will use its influence for uniformity in the sizes of catalogues the better it will be for all of us.

For descriptions of any ordinary apparatus it has occurred to me that if the manufacturers would avail themselves of the advantages of the card system of filing they would get much better results from the reading matter which they send out.

The three principal sizes of cards in inch measurement are 5 by 3 inches, 6 by 4 inches, 8 by 5 inches.

These are about the same size as the metric standard cards of $12\frac{1}{2}$ by $7\frac{1}{2}$ inches, 15 by 10 inches, 20 by $12\frac{1}{2}$ inches.

In each case the metric card is from .05 inch to .13 inch shorter and narrower than the inch cards.

Many business firms have of late been sending descriptions of their apparatus through the mails on cards, writing the address on one side and printing the cuts and descriptions of this apparatus on the other.

Would it not be valuable to the engineer if manufacturers would get out descriptions and cuts of their apparatus on one of the three standard sizes of cards, and have them properly indexed in the upper left-hand corner? When these descriptive cards came in our mail, we could readily file them away in pasteboard boxes, or filing cases, for future reference.

When we write to a manufacturer for descriptions of some pieces of apparatus, how much better it would be for us if it would come to us on a standard size of card, or number of cards, and how much less expense it would be for the manufacturer, than to send a hundred pages or so of stuff that we may never look at. I suggest that members of this Society would often place themselves in the way of expert engineering work if they would exchange with other members of the Society properly indexed cards of their particular line of engineering as, mechanical, electrical, mining, civil, refrigerating, gas, etc. If this card system could be established by the manufacturers, and in fact, by any one desiring to place his apparatus or services before the attention of others, it seems to me probable that money put into catalogues, business cards, etc., would bring better returns to the investor than now.

Mr. H. H. Suplee.—Reference has been made to the *Engineering Index*, and as the matter has been in my hands for a number of years, and we probably file and index as many clippings as any one, our method may be of interest. The index notes are written on cards and are carefully filed by subjects, but the clippings themselves are simply numbered serially. The result is that when

the cards are all filed we have a complete card index and many bundles of clippings. The advertising matter is trimmed off and the clippings folded to nearly a uniform size; they are then placed in bundles of 100, and the numbers—for instance 10,201 to 10,300—printed on the outside of the bundle. The bundles are arranged in serial order along the shelves of the cases in which they are kept. If an article is wanted we look for it in the card catalogue to find its number, and at once go to the clipping of that number and take it out. If there is a gap in the numbers we know that a clipping has been removed. In that way we file 700 to 800 clippings every month from about 200 periodicals in four or five languages, and have recently completed a volume which meant the filing and indexing of more than 40,000 items. The point I wish to make is that filing the clippings by subjects and also indexing them by subjects is simply making two indexes, which is unnecessary. We have found our present method to work very well indeed.

Mr. Geo. L. Fowler.—The regular indexing of engineering literature is, of course, of very great importance to the engineer; but there is another matter which I have found to be of the greatest convenience in my own office, and that is the indexing of trade catalogues which come to me. This Society has approved, I believe, as much as it can approve of anything, and the Master Carbuilders and Master Mechanics have adopted as standards certain sizes of catalogues with a certain definite size of filing case for holding those catalogues. It was pretty thoroughly advertised at the time, and I am sorry to say that most manufacturers absolutely and totally ignored it. It is of the utmost importance for the convenience of an engineer, or for a man who wants to file catalogues, that they should come approximately of the same size. My own practice is to keep a general list of manufacturers of various articles which I may have occasion to use or recommend. When a catalogue comes into my office I measure it. If it measures one of the standard sizes, I open it, go through every page and underscore every item which is manufactured by the publisher of the catalogue, no matter how insignificant it may be, down to such things as mandrels and taps and dies and hangers—little things which are of no apparent importance, and are perhaps side issues with him—all are simply underscored. It is a very large catalogue which I cannot run through and underscore in that way in three minutes. Then I simply throw the catalogue

aside, my assistant takes it and makes out a card index of every one of those underscored items, and the result is that if there is a gentleman in my office talking about a matter and I wish to refer to some underscored item he is talking about—buying some little tool—I can simply ask my assistant to take out all the catalogues in the office which deal with that particular thing, and they are handed to me at once with a delay, perhaps, of a half a minute. But if the catalogues do not measure standard size, I have a very convenient waste-basket at my left in which I deposit them ruthlessly. I have nothing to do with a catalogue which cannot come up to the standard size. I happen to know that I am not the only one who treats them in that way. I think that men in charge of railroad work are doing it more than the engineers who are in other practice, because this matter of the standard sizes of catalogues was brought to their attention more forcibly perhaps than to any other class, and I can simply say that there is a large number of engineers in the country who have a waste-basket for all catalogues that do not come to standard size, and a very convenient filing place for all those that do.

Mr. H. M. Lane.—I agree with the last speaker fully in regard to the method of filing cards and matter, but he has touched upon one point which I have carried a little further. During the last few years I have had to evolve quite a number of filing systems for different purposes. In the system I am at present using I underscore subjects, just as he does, then my assistant makes out the cards and files them; but I have another point in my method which enables me to pull out any set of references by the roots and destroy it. Ordinarily, if a catalogue is discarded there is no way of removing the cards which refer to it in the files, hence the files become full of dead cards, and any one hunting for material runs down a great many references for which he finds no catalogues. When I want to destroy a catalogue I go through the subjects underscored and pick out all of the cards which were made out for the underscored items, and destroy them. When a new edition of a catalogue comes out, I first underscore all of the items which I want to have indexed in it. My assistant then gets the old catalogue and sees if the old reference cards cover the new catalogue. If there are any cards referring to the old catalogue, which are not needed as references to the new catalogue they are looked up and destroyed; if any more cards are required for the new catalogue they are made out, and in this case the new

catalogue is filed in place of the old, taking the same number which the old one had. In case I do not wish to destroy the old catalogue, but wish to file the new one, it has to be treated as an entirely new entry.

Mr. Oberlin Smith.—I believe as thoroughly as anybody can in standard sizes, and I wish we could all come to standards for catalogues, but the brutal method just referred to, of entirely destroying what does not come up to the standard, seems to be something like martyrdom. It is cutting off one's nose to spite one's face. Because a perfectly conscientious maker of machinery may have made the mistake of getting up a catalogue $\frac{1}{2}$ inch the wrong size, it is not good policy for us to at once destroy the catalogue, and the information it contains, by throwing it away. This is not the way to deal with catalogues which do not come to our standard. If this Society could take some definite action on sizes it would be a good thing. Those catalogues which have been standardized, I believe, by the Master Carbuilders and Master Mechanics' Associations, are 12 by 9 inches; then half of that, 9 by 6 inches; and then, instead of halving again as they should do, they go down to 6 by $3\frac{1}{2}$, or something of that kind. I have for a great many years used sizes of drawing paper thus halved, starting with 36 by 24 inches; then 24 by 18 inches; then 18 by 12 inches; then 12 by 9 inches; then 9 by 6 inches; followed by 6 by $4\frac{1}{2}$ inches, $4\frac{1}{2}$ by 3 inches, and 3 by $2\frac{1}{4}$ inches for pads of sketching paper, the latter being ideal for the upper vest pocket. I find this of the greatest convenience, not only for scale drawing paper, but for detail drawing mounted on tin plate, or sheet iron, or pasteboard; also for memorandums, for card indexes, etc. It is better to keep to a universal standard clear through. Catalogues should conform to it, and it is very convenient to have catalogues binarily sub-divided each time so that they will pile up, brick-fashion. Why that odd size was put in the present so-called standards, I don't know, but it ought to be remedied. The little catalogue after the 9 by 6 inches, ought to be 6 by $4\frac{1}{2}$ inches.

Mr. S. Whinery.—One criticism of the method of card indexing described by the author is, that the references do not give a sufficiently definite record of the character of the matter indexed, particularly in the case of articles of a general character which are not devoted to one specific item. It is always unsatisfactory to have to look up a large number of references before finding just what one wants. It will usually save time if the index gives the

character and scope of the article to which reference is made, even if it takes additional time, and costs more to make the more complete index.

The writer puts but one reference on each card, and aims to have this reference convey as fully as reasonable brevity will permit the character and value of the article indexed. Conventional symbols are used for the sake of brevity as follows:

V = Very valuable—full and detailed information.

V^1 = valuable.

V^2 = worth indexing, but not very important.

An underscore, thus, $\underline{V}$, indicates that the article is abstract or

SUBJECT *Water Power.*

ITEM *Plant of St. Croix (Minn.) Power Co.*

REFERENCE *Eng. Rec.* 12, 1, 1900, *p.* 514.

$\oplus$ $\overline{V^1}$

Abstract of pap. before Am. Inst. El. Engs. by H. C. Floy, eng. in chg.

FIG. 277.

theoretical; an overscore, thus, $\overline{V^1}$, shows that the article is descriptive or practical.

$\times$ = illustrated.

$\oplus$ = very fully illustrated.

Doubtless a better scheme of symbols can be devised; this was adopted many years ago, and is adhered to for the sake of uniformity in the index.

A copy of a card (Fig. 277) from the writer's index is given to show the form used and to illustrate the method employed.

*Mr. Soule.**—Taking up Mr. Quick's comments, I will, at the outset, concede that two of his points were very well taken, and I think it quite likely that a larger card than the one which I have

* Author's closure, under the Rules.

described would be advantageous; I myself have at times been puzzled to find abbreviations for long words, and enough of them to get the complete entry on one line of the card. Also, it would be better if the boxes were not as thick as 3 inches; that is particularly so in the larger of my three sizes; there is no difficulty in the small or intermediate size; they can be handled very rapidly. But when you take the large size box, 3 inches thick, and fill it, it takes pretty near a man's strength to handle it, particularly if it is on a lower shelf. But on other points made by Mr. Quick, I must disagree, particularly that the file itself should be classified by subjects; I did not so state in my paper, but it was one of the vital and fundamental points on which I based my structure, that it was not a good idea to undertake to classify the enclosures of your file, because, in doing so, you at once from the very outset sacrifice all your chances for compactness; if you are going to adopt a system of classification in your file you must, of necessity, leave vacant spaces after each subject, and, therefore, multiply very rapidly the amount of storage space required; and if you have an office in lower New York, and have to pay $3 per square foot per year for your floor space, these considerations of economy of storage space become very important. As to Mr. Quick's point that technical papers should be filed in full and without being mutilated, I do not consider that at all necessary; but perhaps it might be so in the case of an engineer who lived at a point away from a metropolitan centre; situated as I am in New York, one can readily get access to the files of all the technical papers, and I do not feel the least necessity of keeping them on my own shelves after having culled out the most important matter, put it in my file, and indexed it.

Two or three of the gentlemen have laid stress on the importance of uniform sizes for trade catalogues. I think the prospect of securing such a desideratum is almost hopeless. I was identified with the movement in the Master Mechanics' and Master Carbuilders' Associations to secure the adoption of their standards for pamphlets and trade catalogues; those two Associations are unique in the one particular that they have a larger following of trade representatives attending their conventions than in the case of any other association in this country; probably more than half of the attendance is made up of supply men, as they are called, and they are almost part and parcel of the Associations; they take part in the deliberations, not officially, but between times and on

the porches of the hotels, and they carry considerable weight; some of their representative men agreed that uniform size for pamphlets and trade catalogues was a very desirable thing, and undertook to put their shoulders to the wheel and accomplish it, but it has been only a partial success. I do not think that the combined influence of all the technical and scientific societies in this country can produce any more results in that respect than have already been accomplished.

As regards the treatment of obsolete matter, it would seem that any system of filing which can be devised will find the owner confronted with that problem; no one of us is far-seeing enough to tell what matter is going to be obsolete even five years from now, and we all lean toward the safe side and put doubtful matter into our files, and there is no other remedy than to cull out the obsolete matter from time to time, if required.

I would like to emphasize and endorse Mr. Quick's suggestion that all pages of a periodical should have the date of publication, name of publication, and page number at the top of each page, so that the user would not have to write the reference on each article taken out. Referring to Mr. Whinery's comments, it might possibly be inferred from the paper that but one index card was made out for each article filed; as a matter of fact, however, several index cards are often prepared, particularly for articles of a general character such as Mr. Whinery refers to, or articles which embody valuable data or tabulated matter not implied by their titles.

No. 947.*

A GRAPHICAL DETERMINATION OF PISTON ACCELERATION.†

BY J. N. LE CONTE, BERKELEY, CAL.

In investigating the inertia effects of the reciprocating parts of the steam engine, the labor of computation may be shortened in many places by the introduction of graphical processes. These consist of geometrical constructions whereby the velocities and accelerations of the various points of the kinematic chain may be determined because proportional to the lengths of lines, and if the scales of the drawing are properly selected, their absolute values become known.

In the following paper a method is presented for finding the acceleration of the cross-head for any given angular position of the crank. The usual graphic solution of this problem is the one originally given by Rittershaus (*Civil ingenieur*, xxv. s. 461), which gives the required quantity as the difference of two lines. This construction, however, fails at the dead points, where the acceleration is a maximum, and for some distance on each side of these points the construction is poor. The method given below finds the acceleration as the length of a single line, but it involves the use of the instantaneous centre of the connecting rod with respect to the engine bed. This passes to infinity when the crank reaches the 90-degree position, and, therefore, for some distance on each side of this the construction is poor. At the 90-degree position, however, the construction is perfectly obvious.

In Fig. 278, let O be the centre of the shaft, C the crank, and D

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* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For further discussion on the same topic, see *Transactions*, as follows:

Vol. viii., p. 191: "Formula for Reciprocating Parts of High Speed Engines." Geo. I. Alden.

Vol. xi., p. 492: "Transmission of Force in a Steam Engine." D. S. Jacobus.

Vol. xi., p. 1116: "Transmission of Force in a Steam Engine, Appendix." D. S. Jacobus.

the wrist pin. Then I is the instantaneous centre of DC referred to the engine bed. Now, when the velocity, CV, of C is constant we know, by a familiar proposition, that OS is proportional to the velocity of D. This proportionality becomes an equality when the scale of velocities is such as to make the velocity of C equal to the crank throw OC, or when $V = R$. Since OS is proportional to the velocity of D, and since it is measured from a fixed point O in an invariable direction, the acceleration of D,

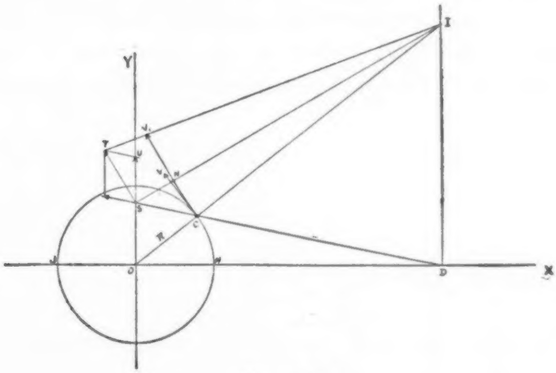

FIG. 278.

which is proportional to the time rate of change of OS, will be proportional to the velocity of S along OY.

Rittershaus also employs the rate of change of OS to find the acceleration of D. He expresses OS as a function of other quantities, and finds its rate of change by the method of differentiation. That is to say, calling $OS = y$, $OD = x$, and angle $ODC = \alpha$,

$$y = x \tan \alpha,$$

$$\frac{dy}{dt} = \frac{dx}{dt} \tan \alpha + \frac{x}{\cos^2 \alpha} \frac{d\alpha}{dt}.$$

He then proceeds to work out a graphical construction for each of the terms entering the equation.

In the present instance we merely consider the axis of the rod DC as extended beyond OY. Then S, when considered a point of DC, is moving at right angles to SI. With I as a centre and radius equal to IC, project C on the arc of a circle to N. Then the velocity of C, which is constant, is equal to the velocity of N, and the velocity of S is ST, by obvious construction. Then by

drawing TU parallel to CD, we find SU equal to the velocity of S along OY. Hence SU is proportional to the acceleration of D. Since the acceleration of C is equal to $\omega \times$ (velocity of C), where ω is the angular velocity about O, the scale of accelerations will be $\omega \times$ (scale of velocities), or, as $V = R$, the scale of accelerations will be such that $OC = R\omega^2$. In other words, the scale of velocities must be such that OC is equal to the velocity of C, and that of accelerations such that OC is equal to the acceleration of C.

At the dead centres the construction reduces to a very simple form. Taking the dead centre on the head end, C and N will coincide with H, I will fall upon D, S will come down to O, and

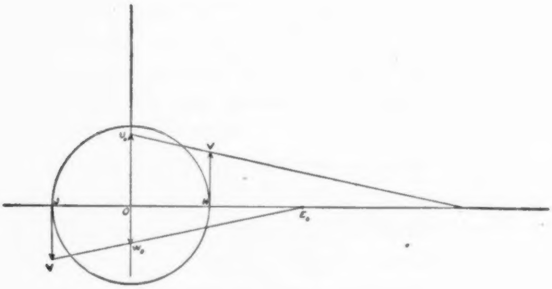

FIG. 279.

ST and SU will unite. This simplified construction is shown in Fig. 279.

Now, returning to Fig. 278 it is evident that SU is also proportional to the force necessary to accelerate a given mass at D, and we merely need to choose a proper scale to make SU represent *Force*. All confusion which might arise in choosing these scales can be avoided by the following simple device. The force necessary to accelerate a mass M at D when the crank is on the dead centre, can be simply computed, for the analytic expression for the acceleration reduces to an exceedingly simple form at this point. Calling this force F_0, we have:

$$F_0 = -MR\omega^2(1 + n),$$

where n is the ratio of crank to connecting rod lengths, or:

$$n = \frac{R}{L}.$$

Having calculated this force in pounds, or other units, we lay it off to any convenient scale as OU_0, Fig. 279, join U_0 to D_0, and HV, the proper scale of velocities, immediately becomes known. This same length, HV, can then be used all around the crank circle to get other values of the inertia forces at D on the same scale as F_0.

A simple example will serve to explain the method still better. Let the weight of the mass moving with rectilinear translation at D be 40 pounds, the throw of the crank be 4 inches, and the

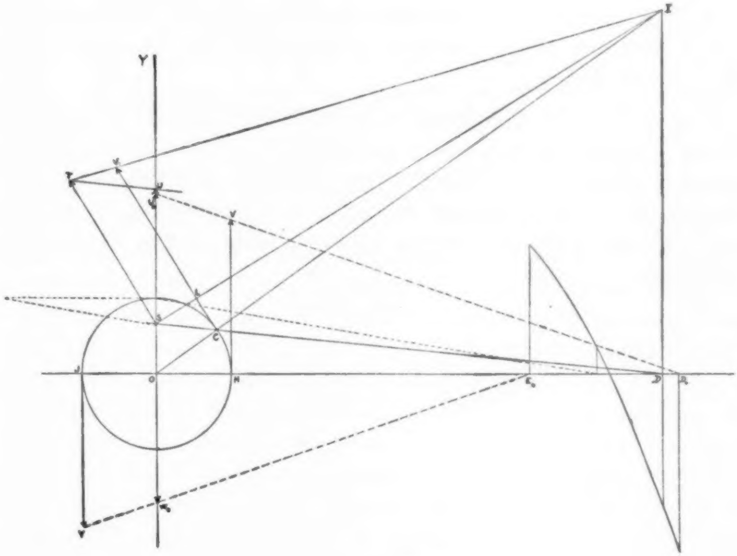

FIG. 280.

length of the connecting rod be 2 feet. If the engine makes 300 revolutions per minute:

$$F_0 = -\frac{40}{32.2} \times \frac{1}{3} \times \left(\frac{2\pi \times 300}{60}\right)^2 \left(1 + \frac{1}{6}\right)$$
$$= -476.77 \text{ pounds.}$$

Choosing a scale of forces equal on the original drawing to 200 pounds to the inch, we lay off $F_0 = OU_0 = 2.38$ inches, Fig. 280. Then $HV = 2.04$ inches. When the crank stands at C, the 30-degree position, $F = SU = 356$ pounds.

The following advantages would seem to be gained by the use of the above method.

1. The construction is the simplest and most effective at the dead points, where the analytical expression for acceleration is the simplest also.

2. The length representing the acceleration is given by a single line, and not by the differerence of two; hence the variation in the acceleration can be studied to greater advantage.

3. The length SU can be made to represent forces or accelerations on any scale whatever without practical difficulty.

4. The construction for obtaining the velocity of S along OY s not obtained from complex analysis, but can be seen on the face of the drawing.

The defect of the method is, that for ordinary values of n, the instantaneous centre I passes beyond convenient reach when the crank is between about 45 degrees and 135 degrees; but, as has been said, the construction is obvious at the 90-degree position, and one point on the inertia curve in that region is generally sufficient.

No. 948.*

SUPPLEMENTARY REPORT OF THE COMMITTEE ON STANDARD PIPE UNIONS.

After the presentation of the report of your Committee on "Standard Pipe Unions," and before its publication, a communication was received from a prominent manufacturer containing criticisms of certain parts of the designs submitted. This communication was in reply to a letter from your Committee enclosing drawings and tables of dimensions of the designs of proposed standard malleable unions prepared by them and subsequently submitted, sent to eleven prominent manufacturers of unions requesting suggestions and criticisms. Since these criticisms reached us too late for consideration in our report—and in view of the absence of discussion of same when presented—we deem it important to submit this supplementary report.

A copy of the report submitted at the New York meeting was sent, under date of April 8, 1902, to the same manufacturers to whom the first letter was addressed, who were again requested to criticise it and offer any suggestions for improvements in the designs. An invitation was also extended to send a representative to this meeting to take part in the discussion which we hope to bring out. Replies have been received from four manufacturers.

One will send a representative to this meeting.

Two believe that the metal in some parts of the designs submitted should be thicker.

One thinks that the unions are generally too long, another that they are too short; while one endorses also the first and fourth objections submitted by the manufacturer making the most definite objections to the Committee's designs, which we give below in full:

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* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

"*First.* The extension A on the thread (Fig. 281) is believed to be unnecessary, adding to the length of the coupling, and to all purposes can be provided for by bevelling off the thread at an angle of 45 degrees, thereby affording protection to the thread and at the same time making it easier to enter the ring.

"*Second.* The lip B on the swivel or tail-piece appears to be longer than required. One-thirty-second inch over the thickness of packing, or say, $\frac{3}{32}$ inch, would appear to be sufficient. This long lip interferes materially in springing the thread and bottom together when making a short connection.

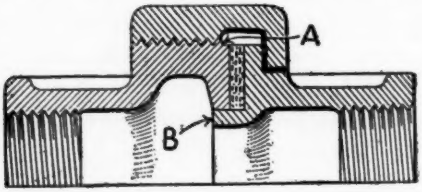

FIG. 281.

"*Third.* The bead C (Fig. 282) on the outer edge of the thread and bottom piece interferes materially with holding in jaws or chucks for threading, and would be better provided for, if material is required for strength, by slightly adding to the thickness of the metal, say $\frac{1}{32}$ inch.

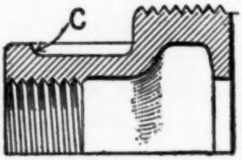

FIG. 282.

"*Fourth.* The section D (Fig. 283) on the bottom is too heavy in proportion to the section E, and will result in loose material and consequent leakage.

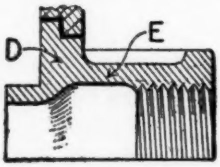

FIG. 283.

"*Fifth.* The length of the union it would appear might be shortened, while at the same time preserving full length in both thread and bottom end.

"*Sixth.* The ogee on the ring might be replaced to good advantage by clean sweep or curve from the flat for the wrench to the face of the ring. The fillet of the ogee, especially on small sizes, is apt to catch and hold sand, which in galvanizing interferes with clean smooth work.

"Trusting that these few suggestions may be of some value to you and thanking you for your courtesy in addressing us on the subject, we remain."

Your Committee have considered the objections raised with the following results:

First. The extension *A* referred to in the communication, was not considered unduly long by your Committee in order to secure the proper protection of the threaded external portion of the union. Should it be found, however, that this could be advantageously shortened by the test of actual experience, such shortening would in no wise affect the question of interchangeability which is of the most vital importance.

Second. The above remarks also apply to the objection that the lip *B* is too long.

Third. It is considered that the bead *C* adds considerably to the strength of the union in the most economical and least objectionable manner. It is also believed that special chucks will generally be used for holding this part, with which the bead would not be objectionable; but both it and the ribs will assist in holding the work with properly prepared special chucks.

Fourth. An examination of a considerable number of broken unions did not disclose loose material at *D*, although in some instances this may occur. If so, the suggestion made to lighten at this point would seem the proper remedy, and could be done without changing any of the established dimensions.

Fifth. The length given in column No. 18 of the recommended design was adopted after careful consideration of the length required to properly grasp the union with pipe tongs, etc., and it is believed that this is not excessive, but is advantageous and desirable.

Sixth. The ogee on the ring was selected mainly to improve the appearance, and can be changed to a single curve if the ogee is found to interfere with smooth work either in moulding or galvanizing.

E. M. HERR,
A. S. VOGT,
GEORGE M. BOND,
WILLIAM J. BALDWIN,
STANLEY G. FLAGG, JR.,
} *Committee.*

Mr. W. D. Forbes.—I want to offer a criticism on this union. You all know that with the advancing pressures we meet trouble

with unions. It seems to me as I understand this to be the union as settled on by the Committee, there are some things radically wrong about it. I call your attention to this. Between the parts is a soft packing. It ought to be held in so that when the steam pressure comes on its inside edge it cannot be blown away. In the union shown we have no support for this soft packing at all. There seems to be in it a thoroughly useless obstruction to the flow of steam, and this shoulder at *B* should be on the outside; in other words, put the packing so that when the pressure comes on it, it will not blow out; and it will not, if supported on the outside, especially if instead of a straight, the two faces are tapered as when the steam strikes the packing, it will tend to make it tighten. The face of the union should be tapered, and if so made tends to become self-tightening.

Mr. H. H. Suplee.—I should like to call attention to a point which I think has been not considered perhaps in this coupling

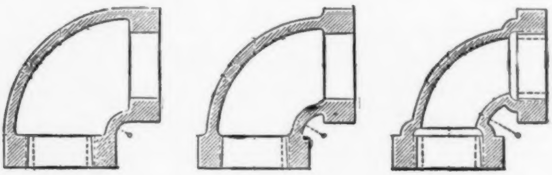

FIG. 284.

and in nearly all pipe fittings; that is, that little or no attention has been paid to making the interior of such a shape as to diminish the friction or resistance to the flow of the liquid. Any change in cross section results in eddying and in loss; and instead of cupping, as a matter of fact, the fitting should be really so made that the bore is nearly uniform. Then, when the pipe is screwed in, it will come up practically so as to meet an opening of its own diameter, so that the cross section of the opening will be neither enlarged nor reduced anywhere in the fitting. This will reduce the resistance to flow very materially, and can be used for any fitting. I know there have been some experiments made with special fittings of that sort with very great advantage as far as resistance to flow is concerned.

Fig. 284 shows three types of fittings, all elbows in this case, but the same principle can be applied to unions, and it will be seen that in the fitting on the right, after the pipes have been screwed

in there will be practically no variation in the diameter of the bore, and the resistance to the flow will be a minimum.

Mr. Forbes.—If that were commercially possible, it would be first rate, but it is not, as you bring your tap up against a bottom. Then, again, the thread might not be tight when the pipe is screwed in to the shoulder.

Mr. Carleton W. Nason.—I would take exception to Mr. Forbes's first criticism. No well-informed steam engineer would think of using a union with a soft packing for high-pressure steam. Such should never be used where a right-and-left coupling or flange union can be inserted. Where this is impossible the union should have a metal seat, and by using a ground surface on the approximately spherical faces, as is done in a number of kinds in the market, an accommodation of angles can be secured which is impossible with packing of any sort.

Mr. Suplee has evidently overlooked the commercial requirement that in running a tapping machine the tap becomes so worn after being used some time that it must be advanced further into the fitting. It is, therefore, necessary to have a recess beyond the thread for the nose of the tap to enter; otherwise it would be necessary to grind off the end of the tap after every 500 holes or so.

*Mr. E. M. Herr.**—I would like to say one word more in regard to that obstruction of flow; that is, that it is more apparent than real—in fact, it does not exist. When the pipe is in, it will be found by examining the actual union that the smallest diameter offers no obstruction to the flow. This diameter is that of the inside diameter of the pipe, and there is absolutely no obstruction, except from the change in shape, which is unavoidable. On account of the difficulty of forming a sound casting, if you have the same thickness of metal carried through, it is necessary to make an inside enlargement at *D*, Fig. 283. The change in section was carefully considered and made as slight as is consistent with practical foundry requirements.

* Author's closure, under the Rules.

No. 949.*

A METHOD OF DETERMINING THE TEMPERATURE OF EXHAUST GASES.

BY R. H. FERNALD, NEW YORK.

(Associate Member of the Society.)

1. In preparing detailed specifications and instructions for conducting tests of gas engines (paper No. 950 presented before this Society at this meeting) the attention of the writer was directed to the necessity of an accurate and inexpensive method of determining the temperatures of exhaust gases. This problem had apparently received little attention, at least not sufficient to develop any simple means of making accurate determinations. In cases in which the results seemed to be reasonable, the apparatus used was far too expensive or too delicate for ordinary conditions, and efforts were at once centred upon the desired solution.

2. In the books at hand on engine tests, no mention is made of any method, and even in the very recent report of the committee appointed by this Society " To Codify and Standardize the Methods of Making Engine Tests," the committee says (paragraph XX.): "The computation of temperatures corresponding to various points in the indicator diagram is, at best, approximate. It is possible only when the temperature of one point is known or assumed, or when the amount of air entering the cylinder along with the charge of gas or oil, *and the temperature of the exhaust gases are determined.*" In the fine-print detailed instructions under the same paragraph the report states, " T′ may be taken as the temperature of the exhaust gases leaving the engine, provided the engine is not of the ' scavenging ' type."

Again, in referring to the value represented by T in formula B of the same paragraph is found the expression, " If T be the observed temperature of the exhaust gases."

* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

3. While references thus made indicate the necessity of obtaining these temperatures, yet nowhere in the report is there any suggestion of a method of making these determinations. Even if pyrometers and thermometers are regarded as sufficiently accurate, yet no measurements made at or near the muffler can give the true temperature of the exhaust gases unless proper corrections be made for the fluctuations in pressure. This at first appears to present little difficulty, but more careful thought shows the fallacy of the first impression.

Consider for a moment the action taking place at the opening

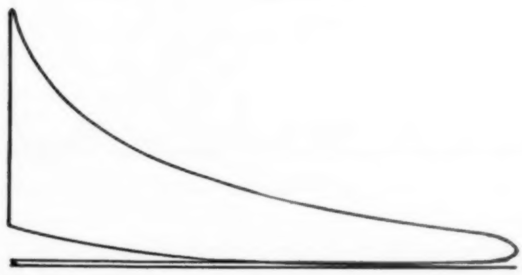

FIG. 285.

of the exhaust. Although the gases in the cylinder have undergone rapid expansion after explosion, yet the expansion is far from complete, and at the point of release the pressure is still relatively high, as shown by a glance at Fig. 285.

4. At the instant the exhaust opens there is an outrush of gases at this high pressure and correspondingly high temperature. Then follows, upon the forward stroke of the engine, a flow of a large mass of gases through the exhaust port, at a pressure little above that of the atmosphere and at a temperature necessarily less than that of the first discharge. In order to make the succession of events more apparent an indicator was attached directly to the exhaust pipe, and the cards obtained, as shown in Figs. 286 and 287, verified the statements just made in regard to the action taking place within the pipe. The diagrams represent the same conditions, the spring used for Fig. 286 being only one-half as heavy as that used in Fig. 287.

5. There is, as it were, a mixture of pressures in the exhaust pipe and muffler, and also a corresponding mixture of tempera-

tures, which must rapidly adjust themselves to an equilibrium of pressures and of temperatures.

Temperatures determined at the muffler are, therefore, not the temperatures corresponding to the pressure at exhaust, but those corresponding to a much lower pressure, which is not determined.

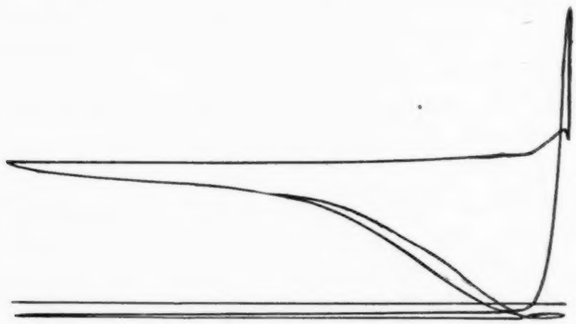

FIG. 286.

This accounts, no doubt, for the very low values of exhaust temperatures which have been reported even by recognized authorities upon gas-engine problems.

The problem, therefore, resolves itself into the determination of the temperatures of the exhaust at some *known* pressure.

6. As a matter of simplicity atmospheric pressure was the natural selection, and a method was at once sought for reducing the

FIG. 287.

exhaust gases to atmospheric pressure without losing any of the heat to which they are entitled.

It was at once decided that a receiver, of a form to be determined, should be placed close to the exhaust outlet of the engine, and some means devised for admitting the exhaust gases and allowing their pressure to fall to that of the atmosphere. The desired temperature could then be ascertained.

7. What the form of the receiver should be was not at first apparent, and, as practically no information could be found bearing upon the subject, the problem was reduced to one of experiment.

The first steps in the development were necessarily very crude and the results were of value only as furnishing a basis upon which to judge future determinations, and as such were of great value.

The first experiments were conducted as follows: Two cylinders of sheet iron were made, one ten inches in diameter and the other fourteen. They were sixteen inches high. The ten-inch cylinder, after being generously perforated near the bottom, was placed inside the fourteen-inch cylinder, the latter having several deep notches cut out at the top. A cover of the same material, and fifteen inches in diameter was made, with a central hole about two and one-half inches in diameter, through which the exhaust pipe from the engine could be passed. A *T* was placed as close to the exhaust outlet of the engine as possible, and from it one line of pipe was run directly to the exhaust muffler, as usual, and the other line brought out horizontally and at right angles to the first, and then directed downward to the receiver just described, the end of the pipe projecting about two inches through the cover, into the inside cylinder. Fig. 288 gives a rough idea of the arrangement.

8. Valves were inserted in both pipes, so that the passage of the gases to the receiver, or to the muffler, or to both at once, could be regulated at will.

In the receiver the gases were passed downward through the inside cylinder, out through the perforations and upward between the two cylinders, finally passing out through the notches in the top of the outside cylinder. The object of this arrangement was to prevent any direct draught or chimney action, which would cause an inrush of cold air at the bottom as soon as the inlet valve was closed. Two holes, large enough to receive the thermometers, were punched in the cover, one midway between the centre and the inner wall and the other about one-half inch from the inner wall. There was no expectation that temperatures even approaching correctness could be obtained by this arrangement, but such a preliminary step was essential in order to have values with which future results could be compared.

9. The exhaust was directed to the receiver, and after being allowed to flow until the cold air in the receiver was entirely

expelled, was shut off and the thermometers quickly inserted. The gases were now held in the receiver at atmospheric pressure. The pressure before closing the inlet was much greater, but dropped almost instantly to that of the atmosphere when the

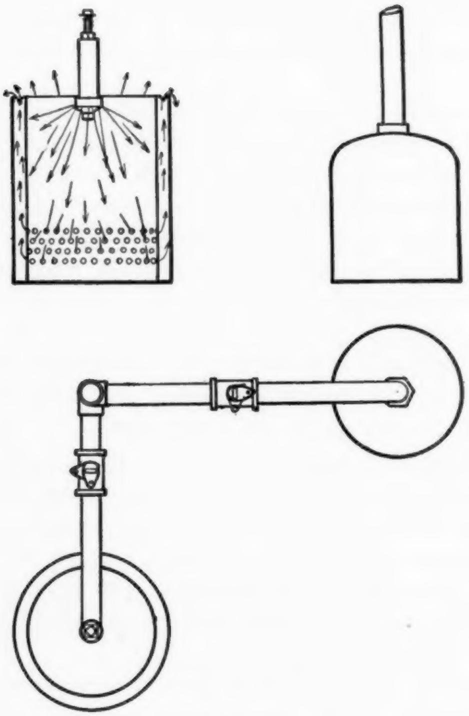

FIG. 288.

valve was closed. The difference in the readings of the two thermometers, one near the wall of the cylinder and the other about two inches from the wall, was not sufficiently marked to be of importance. The temperatures observed were:

370 degrees Fahr.	394 degrees Fahr.	398 degrees Fahr.
395 " "	372 " "	400 " "
	370 " "	

10. Various problems were now to be considered. Radiation and conduction from the cylinders to the outside air might be so rapid as to vitiate the results. The thermometers might be af-

fected by radiation from the inside walls. Radiation from the iron exhaust pipe, which projected into the cylinder, might make the readings too high. Longer runs might tend to cause the cylinders to store up heat.

Many such difficulties had to be considered, and, no data being found bearing directly upon the subject, the experiments were continued.

An asbestos lining was now placed in the outside cylinder, and the temperatures obtained were:

474 degrees Fahr.	511 degrees Fahr.	525 degrees Fahr.
540 " "	553 " "	517 " "

Evidently the gases were retained at a much higher temperature than before, but were these higher temperatures due to excessive storing up of heat, or simply to the prevention of excessive radiation? A similar lining was also placed in the inside cylinder and the temperatures immediately shot up to over 600 degrees Fahr., which were unquestionably far too high. In all of the above experiments radiation through the cover was prevented by an asbestos lining.

11. After considering cylinders of various materials, a clay fire flue 10 inches in diameter was secured and used in place of the inner iron cylinder, the outside iron cylinder with its asbestos lining being retained. The temperatures now recorded were:

360 degrees Fahr.	484 degrees Fahr.	585 degrees Fahr.
388 " "	498 " "	560 " "
405 " "	512 " "	564 " "
442 " "	541 " "	554 " "
465 " "	552 " "	569 " "
469 " "	554 " "	576 " "
	567 " "	

These figures seemed to indicate a gradual storing of heat from the first to about 560 degrees Fahr., when the readings became more constant, but not sufficiently so to warrant the conclusion that the apparatus was nearly correct.

The conclusions at once reached were that the volume for the gases was too small and the thermometers too near the walls. The absorbing of heat by the receiver must also be prevented. In

studying this problem it was seen to be undesirable to allow the gases to enter the receiver at such high pressures and temperatures, and that it would be of great advantage to admit the gases at a pressure and temperature little above those desired at the time of reading the thermometers. This would do away to a large extent with the tendency of the receiver walls to store up heat, as at no time would they be excessively heated.

12. The proper throttling was secured by the device shown in Fig. 289.

It consists of a 2-inch T with a plug in the top, through which passes a $\frac{1}{2}$-inch bolt, and a nipple and cap in the bottom; the bolt

FIG. 289.

is supported by a helical spring, and in turn supports at the bottom a flat iron disk which rests against the 2-inch cap—the bottom of the cap being freely perforated.

By screwing down the nut at the top, against the spring, any desired resistance to the passage of the gases can be obtained, and at the same time any tendency to wire-drawing is obviated, as would not be the case if the throttling were done by means of the valve in the pipe alone.

Before experimenting to any extent with this device for reducing the pressure, a new clay fire flue, 18 inches in internal diameter, with cover of the same material, was obtained. In order as far as possible to prevent any radiation to the thermometer from

the iron pipe delivering the gases to the receiver, the lower end of the device was allowed to pass barely through the cover, extending not over an inch below the inner face.

13. The bottom of the receiver was notched in several places to allow free passage of the gases from within. The gases were thus received at the top, passing downward and out at the bottom.

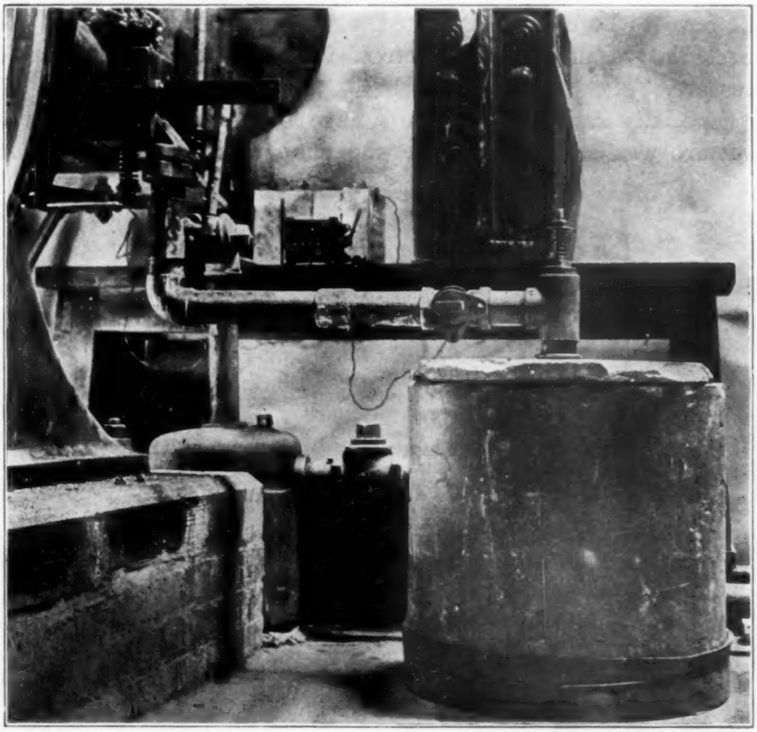

FIG. 290.

A rubber band 3 inches wide was bound about the bottom of the receiver, thus acting as a flap valve, the pressure of the gases entering the pot forcing the band outward, but the falling of the band preventing any inrush of cold air when the admission of the exhaust to the receiver was stopped. In Fig. 290 is shown the completed receiver as attached to the engine.

Many series of experiments have been carried on by means of this device, with most satisfactory results. With the feed so adjusted that the exhaust entered the receiver at a pressure but little

above that of the atmosphere, the storing of heat in the walls was practically prevented.

14. In case the exhaust was delivered to the receiver for an hour or more without ceasing there was a slight rise in temperature, but as in practice the exhaust is cut off about every 10 minutes no difficulty is experienced from this cause.

The pressure under which the exhaust enters the receiver does not have to be closely regulated, as a slight difference does not affect the resulting temperatures, when taken at atmospheric pressure.

Especially satisfactory results have been obtained when the pressure was so regulated that the temperature of the gases in

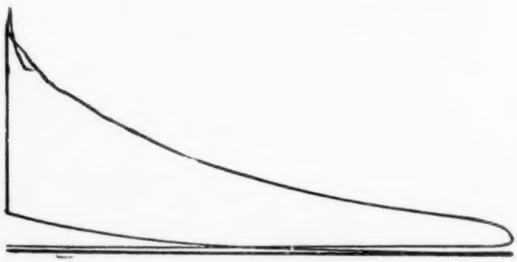

FIG. 291.

the receiver, while under pressure, was between 50 degrees and 100 degrees above the temperature at atmospheric pressure.

15. One or two preliminary tests will quickly determine what this temperature should be. The temperatures recorded from the new receiver did not range from 400 degrees Fahr. to over 600 degrees Fahr. but were:

200 degrees Fahr.	202 degrees Fahr.	203 degrees Fahr.
195 " "	201 " "	200 " "
195 " "	203 " "	200 " "
	203 " "	

The radiation from the receiver was not large. The walls were 1 inch thick and the hand could at all times be held on the outside.

Any change in the conditions tending to change the temperatures of the exhaust is quickly noticed by a corresponding change within the receiver. For example, if the point of ignition be changed, a corresponding change in temperatures is immediately

observed. With the point of ignition as shown by the diagram, Fig. 291, the following temperatures were recorded:

199 degrees Fahr.	197 degrees Fahr.	197 degrees Fahr.
198 " "	196 " "	198 " "
198 " "	196 " "	198 " "
	199 " "	

Fig. 292.

16. With the ignition retarded as shown by Fig. 292, the temperatures were:

210 degrees Fahr.	210 degrees Fahr.	207 degrees Fahr.
216 " "	212 " "	212 " "
214 " "	211 " "	209 " "
	210 " "	

While making this particular series of experiments on points of ignition, the engine became stalled when set for a certain point of ignition and refused to run. The igniter was removed and

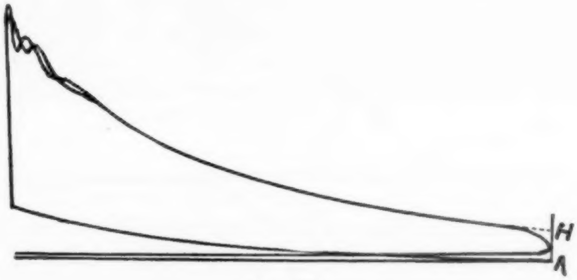

Fig. 293.

found to be badly burned. It was adjusted for sharper contact and a new series of readings taken.

An immediate drop of about 50 degrees in the temperature re-

sulted, showing at once the quick response of the receiver to changed conditions. The spark was now sharp and short, while previously the condition of the sparker was such that it was "holding fire."

The new series on the variation of the point of ignition resulted

FIG. 294.

as follows, the temperatures in each column corresponding to the point of ignition shown in the diagram having the same number as the column of temperatures:

For Fig. 293.	For Fig. 294.	For Fig. 295.
151 degrees Fahr.	166 degrees Fahr.	172 degrees Fahr.
149 " "	168 " "	176 " "
151 " "	168 " "	178 " "
152 " "	167 " "	175 " "
152 " "	167 " "	178 " "

17. Owing to the size of the receiver and to the necessity of having other connections made to the engine, the exhaust pipe

FIG. 295.

leading to the receiver was longer than desired, having a drop of about 1 foot and a horizontal length of 27 inches.

The question of the necessity of covering the pipe, to prevent excessive radiation in conducting the hot gases to the receiver, was quickly settled by the following temperatures obtained:

Covered.	Not Covered.
155 degrees Fahr.	160 degrees Fahr.
155 " "	158 " "
154 " "	158 " "
156 " "	155 " "
158 " "	156 " "
158 " "	157 " "
158 " "	156 " "
160 " "	157 " "

Having become satisfied that the apparatus as outlined was working with a reasonable degree of accuracy, the next step was to devise a receiver which can be erected quickly and cheaply, as it

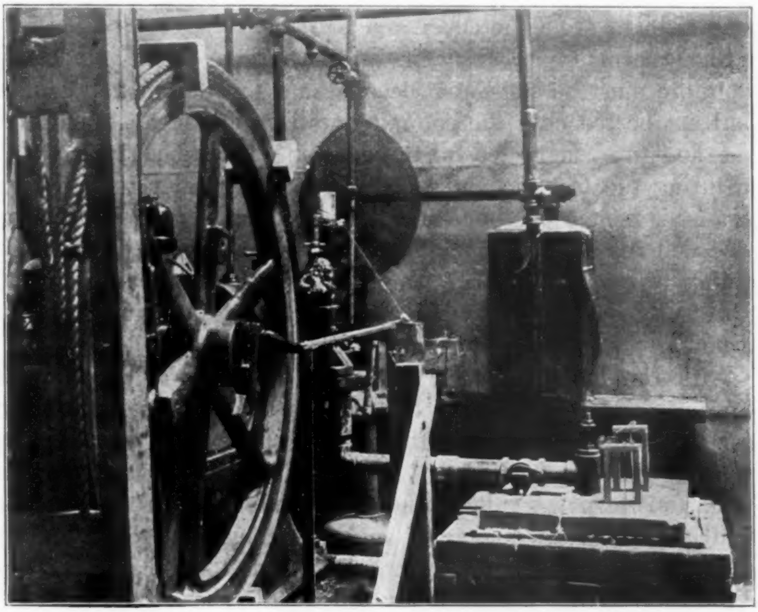

FIG. 296.

is not always convenient to procure a fire flue of the right size. Accordingly, a receiver was built of ordinary brick laid together loosely, as shown in the cut, Fig. 296.

18. This receiver was made of two layers of brick, the inside layer being laid on the face and breaking joints, the outside layer being laid on edge, thus breaking joints both vertically and horizontally with the inner layer. While the cracks furnished sufficient passages to prevent any overcharging of the receiver, yet the break-

ing of the joints prevented direct draughts, or inrush of cold air. As first constructed, the volume of the new receiver was made equal to that of the 18-inch fire flue previously used, and the fire flue cover was fitted to the new receiver. The results were highly satisfactory, the temperatures being the same as before.

The interior was then partially filled with brick until the volume was reduced from 16 by 16 by 23 to 16 by 16 by 13, and again tested, with the same results.

In all of these tests with the two larger receivers the thermometer bulbs were kept about 4 to 7 inches away from the walls and from the entering pipe. In the last receiver, when partially filled with brick, the thermometer bulbs were placed about the same distance from the cover and bottom.

19. It seems unnecessary, therefore, to have excessive volume, but there must be sufficient space so that the thermometer bulbs shall not be too near the retaining walls. Experiment indicates that the figures suggested for these distances are about right.

During the test the valve leading to the muffler in the main exhaust is kept wide open, unless the exhaust pipe is larger than is needed for the quantity of exhaust, and the valve in the pipe leading to the receiver is opened as desired. It is necessary to expel fully the cold air in the receiver before any readings can be taken.

With the larger receiver and an 8 horse-power engine this required about 20 minutes. The time can be much reduced when desired, by careful manipulation of the valves after one becomes familiar with the apparatus.

20. It is of great value to keep suspended within the receiver at all times a thermometer of sufficient range not to be broken by accidental increase of temperature. In the initial warming of the receiver this thermometer will readily show when the temperature has become constant. It also serves as a very efficient guide in adjusting the pressure as controlled by the inlet. For most of the readings taken the pressure was so regulated that this permanent thermometer recorded, while the gases were still under pressure, temperatures from 50 degrees to 70 degrees Fahr. higher than the final temperatures at atmospheric pressure.

The clay cover not being obtainable in all cases, gave way to one made of 2-inch plank, chinked with cotton waste, and this has proved entirely satisfactory.

21. Previous methods of measuring the temperatures of the

exhaust have in most cases furnished results which were surprisingly low, and not until Professor Robertson's paper on "An Efficiency Test of a One-hundred-and-twenty-five Horse-power Gas Engine" (Vol. XXI. *Transactions* A. S. M. E., p. 396), has the writer seen a series of temperatures for the exhaust, which seemed reasonably accurate. Professor Robertson secured by means of a copper-ball calorimeter values above 1,000 degrees Fahr., and in one instance records 1,209 degrees Fahr., occasioning this remark by Professor Thurston: "The possibilities of still further thermodynamic gain are indicated by the temperature of the exhaust gases, above 1,000 degrees Fahr., and far above that of the prime steam of our steam engines."

In Professor Robertson's second paper upon the same subject (*Transactions*, Vol. XXII., p. 612) he reports temperatures of the exhaust, as found by a La Chatelier pyrometer, ranging from 1,410 degrees Fahr. to 1,805 degrees Fahr., and states: "These temperatures appear to be rather high—so high in fact that the author has examined other data at hand to see if any confirmation of the above figures could be found."

It is the opinion of the writer that the last figures quoted by Professor Robertson are not far from correct for the engine tested, but the pyrometer used is far too expensive and requires too much special apparatus, as well as special calibration, to make its use possible in most tests.

22. It takes but a moment's consideration of the problem to show that very little if any thermodynamic gain is possible by any attempted reduction of the temperatures of exhaust, in the average gas engine of good modern design, unless accompanied by a reduction of the terminal pressure as shown by the expansion curve.

23. With terminal pressures ranging near 50 pounds it is quickly shown that the exhaust temperatures must of necessity be much higher than generally recorded. Suppose, for example, that the expansion line of the card shown in Fig. 293 be continued to full cylinder volume, as shown by the point H.

The pressure at H is found to be 50 pounds absolute. Suppose the temperature of the mixture in the cylinder, composed of air and gas, taken in during the suction stroke and mixed with the neutral gases filling the clearance space, to be only as high as that of the room, say 70 degrees Fahr., or 529 degrees absolute at the point A, Fig. 293.

Since the volume at H is the same as that at A, the absolute temperatures will be proportioned to the absolute pressures, or it

T_a = absolute temperature at $A = 529$ degrees,

P_a = absolute pressure at $A = 14.7$ pounds,

P_h = absolute pressure at $H = 50$ pounds,

then T_h, the absolute temperature corresponding to the pressure at H will be derived from $T_h = T_a \frac{P_h}{P_a}$; $T_h = 529 \frac{50}{14.7} = 1{,}800$ degrees absolute or 1,341 degrees Fahr. with the temperature of the mixture taken at 70 degrees Fahr. only. Actually the temperature of the mixture is much higher than this, and by means of the new apparatus described in this paper this temperature is readily deduced. The temperature secured at atmospheric pressure by means of the exhaust receiver is the temperature of the neutral gases that fill the clearance space of the cylinder. The method for determining the temperature of the mixture after having obtained the temperature of the exhaust gases is described in detail in paragraph 29 of paper No. 950, presented at this meeting.

DISCUSSION.

Mr. A. J. Frith.—The method of the author of only measuring the temperature of the gases quiescently at atmospheric pressure appears to be unquestionably correct. We are all aware of the erratic results obtained and recorded in many tests of exhaust gases and steam temperature; and as it was evident that the temperatures as given could not be correct, it has been believed that these low figures indicated a loss, due to an absorption of heat, occasioned by the contact of the hot gases with the metallic surfaces of the valve and its seat, and could not be eliminated. It would appear that at least a large part of this difference in temperature was the result of the change of pressures, and the method described certainly allows of our obtaining figures which are, to say the least, very nearly reliable.

I would ask Mr. Fernald whether he has noticed anything in his experiments which would indicate whether a loss of heat by direct contact with the metallic surfaces of the valve is appreciable, and what it might amount to in percentages or degrees.

Mr. H. H. Suplee.—I should like to call attention to some tests which have been made in the mechanical laboratory of the Tech-

nical High School at Karlsruhe by Professor Straus. In the course of some tests of an Otto gas engine he observed that there was considerable energy in the exhaust gases, and saw that if this were not taken into account there might be a material error in

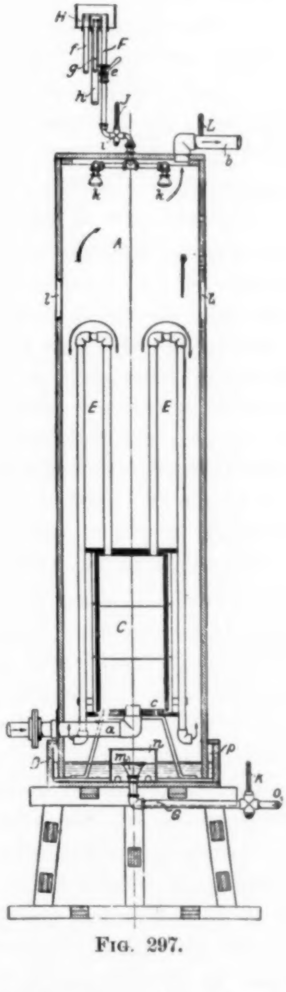

FIG. 297.

the heat balance. He therefore devised a special form of calorimeter for measuring both the heat and the mechanical energy in the exhaust by converting the latter into heat, and, as the matter is of some interest, I append an account of the apparatus and its use. A full account of it, with data and results of tests, will be

found in the *Zeitschrift des Vereines Deutscher Ingenieure* for May 3, 1902, pp. 649, 650.

As shown in Fig. 297, the calorimeter consists of a tall cylindrical chamber *A*, made of wood encased in sheet-iron, supported on a base *B*, and containing an inner chamber *C*, and piping *EE*, together with the water inlet *F*, and discharge *G*. The exhaust gases from the gas engine enter at *a*, passing directly into the inner chamber *C*, which in this case is made of three sections of an old Meidinger furnace. This chamber is closed by lids, bolted on top and bottom, and is provided with a small hole *c*, for the escape of the water produced by the combustion. From the top of the chamber *C* connect six sets of pipes *EE*, arranged in a circle, these extending first upwards and then by the use of two elbows downwards nearly to the bottom of the main chamber. The exhaust gases, after having passed through these pipes, have nearly all their force abstracted, and pass quietly upwards and off through the pipe *b*, into the outer air.

The overflow chamber *H* at the top maintains a uniform pressure of water, and by a cock *e* the flow into the calorimeter can be regulated. The water enters at *g* and flows to the cylinder jacket by the pipe *f*; *h* being an overflow. The temperature of the inflowing water is taken by the thermometer *J*, after which the water passes the four sprays *kk*, thus mingling with and cooling the exhaust gases, and collecting at the bottom and flowing off by the outlet pipe *G*, the discharge temperature being taken by the thermometer *K*. In the water-seal at the bottom *p* it is easy to observe whether the level is raised by any pressure within the calorimeter, in which case the flow of cooling water is increased until the pressure is removed. We thus have the necessary data to determine the entire energy delivered in the exhaust gases—namely, the temperature of the inflowing water, and of the discharge, and the volume of water, this latter being determined by having the discharge deliver from *O* into a calibrated tank. The gases have their mechanical energy checked and thus converted into heat, and the whole quantity of heat is absorbed by the water, and so put into shape for precise measurement.

In the case of a test described by Professor Staus, the sum of the heat in the indicated work, the cooling water in the jacket, and the discharge water from a calorimeter of the above type, came within 1.8 per cent. of equalling the total heat of combustion

of the illuminating gas supplied to the engine, as determined by the Junker calorimeter.

*Mr. Fernald.**—In answer to the questions in regard to temperature, the temperatures recorded, 200 degrees Fahrenheit, are the temperatures of the exhaust gases at atmospheric pressure. The exhaust pressure at the point of release is approximately 50 pounds—that is, 40 to 50 pounds per square inch. When the calculations were made for the temperatures corresponding to those pressures, the resulting temperatures of 1,000 to 1,800 degrees Fahrenheit follow. The temperatures directly measured are for atmospheric pressure and not for the pressure at which the exhaust leaves the engine.

In regard to temperature of the passage through the valves, I have no record. It would be a very difficult point to determine. The question of defect due to the radiation of pipes leading to the receiver was checked carefully with pipes covered and uncovered, and no serious defects were found when the engine was exploding regularly.

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* Author's closure, under the Rules.

No. 950.*

WORKING DETAILS OF A GAS ENGINE TEST.†

BY R. H. FERNALD, ST. LOUIS, MO.

(Associate Member of the Society.)

1. CONSIDERING the rapid advance of the gas engine‡ during the past few years, it is surprising to find how little has been done toward standardizing such engines, or at least toward adopting some form of test whereby a definite idea of the relative merits of different engines can be obtained. Of late years the market has been crowded with various types and modifications of heat engines, especially of the explosive type, many of which are mere freaks and of little or no value.

2. Although a very few types have received the careful attention of the expert, many engines thrown upon the market are the results of a desire to invent, with the possible chance of "hitting the right thing," or are the product of dull times in machine shops.

Although in the case of the steam engine occasional forms are produced having entirely new features, yet the tendency is to conform closely to a general standard which usage and careful investigation have shown to be desirable.

3. Similar standards should be adopted for the gas engine as rapidly as possible. This does not prohibit or discourage invention or modification, which are very essential in the present condition of these engines, but something should be done to classify and standardize those already on the market, thus determining what experience and study have thus far shown to be good form.

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* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For further references on this subject see *Transactions* as follows:

Vol. xxii., p. 152: "Efficiency of a Gas Engine as Modified by Point of Ignition." C. V. Kerr.

Vol. xxii., p. 612: "Efficiency Tests of a One-hundred and Twenty-five Horse-power Gas Engine." C. H. Robertson.

‡ The term "gas engine" is used throughout this paper to include engines commonly termed oil engines.

The problem in its entirety is a large one, and will require many months or perhaps years of continued investigation and study. With this fact in mind, the writer has undertaken a few months' study of the subject, and although unable more than to begin the work, the results so far obtained may prove of interest to this Society.

4. Before the engines can be standardized some definite method of determining the relative merits of different engines must be settled upon, and this leads at once to the necessity of a standard method of testing gas engines, which will form the special part of the problem herein discussed.

It is of interest, before taking up in detail the method of conducting the tests, to note some of the items which require careful investigation and study for a proper classification of the engines. Much of the data desired is simply for general information, and to obtain the views of the manufacturer on certain points and to determine what he considers good practice.

Other information is needed because it enters into any test of the engine which may be made, while other questions lead toward a classification of such engines into general divisions. Although time has not permitted the testing of such data sheets practically, yet the following general form serves as a basis for beginning the investigation and experience alone can determine the necessary modifications and additions:

GAS ENGINE DATA.

No.......... Test No..........

Date..............................

1. Name of Engine..
2. Manufactured by ....
3. Is it two or four cycle?..
4. Kind of fuel used..
5. Assumed heat of combustion of fuel =..........B. T. U. per ....
6. Actual horse-power ....
7. Floor space occupied ....
8. Height, wheels to clear floor..
9. Weight ....
10. Number of cylinders ....
11. How are cylinders arranged if more than one?..
12. Diameter and weight of flywheel. Diam.= ......ins. Wgt.=.......lbs.
13. Diameter and width of brake pulley. Diam.=.....ins. Width=.....ins.
14. Diameter of piston=.....ins. Length of barrel=.....ins. No. rings.....
15. Piston displacement=............cu. ft. Clearance=...........cu. ft.
16. Length of stroke=..........ins. Length of connecting-rod=......... ins.
17. Revolutions per minute= ....
18. Kind of governor ....
19. Method of governing..
20. Special governor features ....
21. Kind of ignition : (*A*), hot tube ; (*B*), flame ; (*C*), electric.

If (*A*) { (*a*) location ....(*b*) dimensions..................
(*c*) how heated ....

If (*B*) { (*a*) kind ....(*b*) size of flame port............
(*c*) special features ....

If (*C*) {
(*a*) contact spark { (1) current required..........(2) voltage...
(3) battery recommended ...(4) number...
(5) specifications of coil ....
(*b*) jump spark { (1) current required........ (2) voltage...
(3) kind of plug............(4) location ..
(5) battery recommended....(6) number ..
(7) specifications of coil..................

22. Kind of valves...
23. Special features of valve mechanism ....
....
24. Diameter of (*a*) gas valve......ins.; (*b*) air valve......ins.; (*c*) mixture valve ..... ins.; (*d*) exhaust valve......ins.
25. Lift of (*a*) gas valve........ins.; (*b*) air valve........ins.; (*c*) mixture valve ......ins.; (*d*) exhaust valve......ins.
26. Kind of { (*a*) carburettor.........................
(*b*) vaporizer ....
(*c*) mixer ....
27. Means of maintaining constant proportions.......................
....
28. Method of fuel feed...
29. Number of water inlets ....diameters..................ins.
30. Number of water discharges..............diameters..................ins.
31. Best rate of water feed ....
32. Kind of muffler...
33. Dimensions of muffler...
34. Does muffler use water?...
35. Means for preventing noise at air inlet.............................
....
36. Kind of gas bag ....
37. Dimensions of gas bag ....
38. Means of clearing engine of exhaust gases...........................
....
39. Devices for starting or aiding starting..............................

5. The investigations which have developed the details of conducting tests have been carried on at the mechanical laboratory of Columbia University during the present college year. The various experiments have been developed largely from work on a 6 x 12½ Otto engine, and a 6 x 9 Nash engine. Much time has been devoted to working out many details and to following incidental suggestions which offered themselves as the work progressed, and it is proposed to present rather fully many important points. This may seem unnecessary to those already familiar with such work, but it is believed that this part of the paper may prove of interest and value to those who propose undertaking such tests for the first time. For this reason some of the difficulties and errors which are likely to occur are especially emphasized.

6. It is hardly necessary to offer any explanation of the items called for in the "log" of the test, as information may be obtained regarding each of these points from the details of the corresponding items which appear in the final report. The form

of "log" appended is found to be convenient for making the preliminary records:

Date..............................
Log of..................Gas engine test............ Test No............
By..............................
Object..............................
Length of brake lever..............................ft.
Weight of brake lever..............................lbs.
Cubic feet of vapor per pound of..............................
Weight of gallon of..............................lbs.
1. Number of run..............................
2. Time..............................
3. Speed and explosions, revolutions per minute, hand indicator..............
4. " " reading of speed counter..............
5. " " explosions per minute, special count..............
6. " " reading of explosion counter..............
7. Total load on scales..............................lbs.
8. Temperatures, degrees Fahr. or Cent., gas..............
9. " " " " air..............
10. " " " " jacket water, entering..............
11. " " " " " " leaving..............
12. " " " " " " barrel..............
13. " " " " exhaust, observed..............
14. " " " " " at pressure of atmosphere...
15. Valve index reading, gas..............................
16. " " " air..............................
17. Areas of valve openings, gas or vapor..............................sq. ins.
18. " " " oil.............................. "
19. " " " air.............................. "
20. " " " mixture.............................. "
21. " " " exhaust.............................. "
22. Weights and volumes, weight of jacket water..............................lbs.
23. " " reading of gas meter, cu. ft.......or gals. of........
24. " " reading of air meter..............................
25. " " gas for igniter..............................cu. ft.
26. Indicator springs used, power card..............................
27. " " " compression card..............................
28. Pressures, gas, inches of..............................
29. " air, inches of..............................
30. " jacket water, lbs. per sq. in..............................
31. " exhaust, lbs. per sq. in..............................
Remarks..............................

7. Before entering upon a discussion of a complete test of a gas engine it is necessary to establish certain standard units. Without question the proper unit for the energy derived from the fuel used is the "British Thermal Unit," which has been adopted throughout this country and England, and is designated in this paper by the usual symbols, B. T. U. In like manner the term horse-power is used to designate the rate of work, and I. H. P. and B. H. P. have their usual significance, meaning indicated horse-power and brake horse-power respectively.

Further explanation of the units used will develop during the examination of the final report. It is hardly necessary to touch upon the proper methods of calibration of instruments to be used,

with the exception of special instruments or instruments used under special conditions, as this subject has been so fully treated in many previous publications. These cases will be treated under their respective heads.

PRELIMINARIES OF THE TEST.

8. Before beginning the test it is very essential to see that the engine is in good running order, thoroughly oiled, and properly adjusted. All valves should be carefully examined and adjusted. All connections to the engine, whether fuel, air, or water, should be tested for leakage.

Special note should be made of any points out of the ordinary, and if they are of such a nature as to affect the results of the test, the difficulties should be set right as far as possible, and, when this cannot be done, careful estimates should be made of the changes in the results due to such conditions.

It is of the greatest importance that each observer know exactly what is expected of him, and that he be made thoroughly familiar with the details of at least all apparatus and machinery bearing upon his portion of the work and he should be shown exactly what to do in case of emergency, in order to rectify difficulties as quickly as possible without interrupting or possibly destroying an entire test.

9. In the series of tests from which the results for this paper were obtained, more than one test was entirely lost after hours of work through the hasty action or lack of judgment of some one observer. Where possible, a picked and trained crew should be retained, and even then as far as practicable the director of the test should attempt nothing but the oversight of the observers, and should stand ready for all emergencies, allowing the individual observer to touch nothing but the instrument he is observing, and then only as directed. Unfortunate experience has shown this to be the only possible way of obtaining reliability in results.

It is necessary that the engine be run a sufficient time before the real start of the test, to enable all parts to become properly adjusted to the desired running conditions, or to get the engine "warmed up," and to determine accurately the proper working of all instruments and recording devices, and especially if the engine is to carry the maximum load which it can carry continually. Much difficulty is often experienced in determining this

maximum load, especially if the fuel used is city gas, for then the load carried yesterday may be far from the possible load of to-day. If a brake is used without cooling water, then the run previous to the start of the test must be of sufficient length thoroughly to warm the brake pulley, to permit further expansion and a sudden increase in the load. A brief preliminary trial should in every case precede the regular run, to make certain that every observer understands his work, and it is found advantageous not to inform the observer of any distinction between the preliminary run and the true test.

The reading of an ordinary meter used for measuring air supply is not a difficult matter, but it has been found that few men can obtain reliable readings without previous experience.

OBJECT OF THE TEST.

10. It is absolutely necessary that the object of the test be definitely determined, and this object should be kept constantly in mind during the run, whether the test be a general efficiency test, a test for proportions of air to gas, changes in conditions of ignition, temperature of jacket water, throttling of exhaust, or what not.

FORM OF REPORT BLANK.

11. Careful study coupled with experience has developed the accompanying form for the final report of the test. At first sight it may appear to some as too comprehensive, consequently cumbersome, but the desire has been to secure a form which will serve for all purposes, whether for an efficiency test only or for a complete laboratory test in which much datum is desired for further study that might of itself be of little value to the manufacturer directly, but of great value scientifically, especially along lines which will aid in further development of the heat-engine problem.

It is deemed wise to take up each item of the report in detail, and, to assist in making the explanations clear, run number 6 has been selected from each of the two tests chosen for this paper.

The engine from which the results recorded as test "A" were obtained was run under full load, while in making test "B" the engine carried only half load.

12. It is not intended to draw any comparisons between the two runs, and they are both submitted simply to assist in further

Date, *January* 15, 1902.

Report of................"A" ....Gas Engine Test.

Test No...

By...

Object......................*Efficiency, Proportions of Air to Gas* ....

1.		Number	1	2	3	4	5	6	7	8	9	10	Totals.	Average.
2.		Time intervals, minutes	10	10	10	10	10	10	10	10	10	10	100	10
3.	Revolut's and Explosions.	Total revolutions	2,979	2,959	2,884	2,775	2,812	2,679	2,728	2,758	2,675	2,856	28,105	2,810.5
4.		Revolutions per minute (mean)	297.9	295.9	288.4	277.5	281.2	267.9	272.8	275.8	267 5	285.6	2,810.5	281.05
5.		Total explosions	1,369	1,329	1,393	1,293	1,400	1,339	1,344	1,379	1,335	1,393	13,574	1,357.4
6.		Explosions per minute (mean)	136.9	132.9	139.3	129.3	140.0	133.9	134.4	137.9	133.5	139.3	1,357.4	135.74
7.		Ratio of revolutions to explos's	2.18	2.22	2.07	2.14	2.01	2.00	2.03	2.00	2.00	2.05	20.70	2.070
8.	Jacket Water.	Weight in lbs	97	97	97	97	97	97	97	97	97	97	970	97
9.		Weight in lbs. per hour	582	582	582	582	582	582	582	582	582	582	5,820	582
10.		Temperature range	72	72	76	78	74.5	72	72	74	74	77	741.5	74.15
11.		Max. velocity, feet per second	....	....	....	....	....	....	....	....	....	....	....	....
12.		Heat absorbed, B. T. Units	6,980	6,980	7,370	7,760	7,220	6,980	6,980	7,180	7,180	7,460	72,090	7,290
13.	Air.	Cubic feet	198.0	196.2	193.2	190.6	193.0	194.0	195.5	197.0	195.5	196.0	1,949.0	194.9
14.		Cubic feet per hour	1,188	1,177	1,159	1,144	1,158	1,164	1,173	1,192	1,173	1,176	11,704	1,170.4
15.		Temperature, Fahr. deg	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	....	....
16.		Weight per cubic foot	.0727	.0727	.0727	.0727	.0727	.0727	.0727	.0727	.0727	.0727	....	....
17.		Max. velocity, feet per second	....	....	....	....	....	....	....	....	....	....	....	....
18.		Specific heat, c_v	.1691	.1691	.1691	.1691	.1691	.1691	.1691	.1691	.1691	.1691	....	....
19.	Fuel *Gas.*	Cubic feet or ~~gals~~	29.00	28.25	28.50	27.50	27.50	26.25	24.50	25.75	26.00	27.00	270.25	27.025
20.		Cubic feet or ~~gals~~ per hour	174.0	169.5	171.0	165.0	165.0	157.5	147.0	154.5	156.0	162.0	1,621.5	162.15
21.		Temperature, Fahr. deg	86	86	86	86	86	86	86	86	86	86	....	....
22.		Weight per cubic foot	....	....	....	....	....	....	....	....	....	....	....	....
		" " gallon	....	....	....	....	....	....	....	....	....	....	....	....
23.		Max. velocity, feet per second	....	....	....	....	....	....	....	....	....	....	....	....
24.		Specific heat, c_v	.1691	.1691	.1691	.1691	.1691	.1691	.1691	.1691	.1691	.1691	....	....
25.		Cubic feet Standard Gas per hour (60° Fahr., 14.7 lbs. press.)	166.5	162.5	163.5	158.0	158.0	151.0	141.0	148.0	149.5	155.0	1,553.0	155.3
26.	V Index Reading.	Gas	5	5	5	5	5	5	5	5	5	5	....	....
27.		Air	....	....	....	....	....	....	....	....	....	....	....	....

No.	Group	Item												
28.	Values of n in Eq. $PV^n = P_1V_1^n$ for expansion curve.	....	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	11.40	1.14
29.	Mixture.	Temperature, Fahr. deg.	108	108	108	107	108	106	106	106	106	107	1,070	107
30.		Weight, per cubic foot	.0698	.0698	.0698	.0700	.0698	.0701	.0701	.0701	.0701	.0700	.6996	.06996
31.		Max. velocity, feet per second	......	......	......	......	......	......	......	......	......	......	......	......
32.	Pressures from Indicator Cards.	Pressure at end of Comp.	91	91	91	91	91	91	91	91	91	91	910	91
33.		Max. pressure or pressure at beginning of expansion	312	310	307	307	307	298	298	302	302	302	3,045	304.5
34.		Pressure at end of expansion	55	55	55	55	53	53	50.5	53	55	55	539.5	53.95
35.		Pressure if expansion be carried to end of stroke	51.0	51.0	49.5	49.5	49.5	48.0	47.0	48.5	49.5	49.5	493.0	49.3
36.		Mean effective pressure	68.0	70.6	67.9	66.0	62.0	66.3	68.5	71.5	67.7	67.7	676.2	67.62
37.	Exhaust.	Temperature Fahr. deg.	1,510	1,510	1,450	1,445	1,450	1,387	1,350	1,410	1,445	1,450	14,407	1,440.7
38.		Max. velocity, feet per second	......	......	......	......	......	......	......	......	......	......	......	......
39.		Specific heat, c_v	.1691	.1691	.1691	.1691	.1691	.1691	.1691	.1691	.1691	.1691	......	......
40.	Ratios.	Air to gas to	6.2	6.1	6.5	6.4	7.0	7.4	7.9	7.6	7.5	7.1	69.7	6.97
		Neutrals	1	1	1	1	1	1	1	1	1	1	10	1
			2.2	2.2	2.3	2.2	2.4	2.4	2.6	2.5	2.4	2.4	23.6	2.36
41.		Stroke to Expansion	1.15	1.15	1.15	1.15	1.15	1.14	1.14	1.14	1.14	1.16	11.47	1.147
42.		Vols. v_2 to v_1	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	46.80	4.68
43.		Max. pressure to M. E. P.	4.59	4.39	4.52	4.65	4.95	4.50	4.35	4.22	4.46	4.46	45.09	4.509
44.		Max. pressure to comp. pressure	3.43	3.41	3 38	3.38	3.38	3.28	3.28	3.32	3.32	3.32	33.50	3.35
45.	Value of R		.970	.970	.970	.972	.970	.973	.973	.973	.973	.972	9.716	.9716
46.	Temperature, Fahr. deg. at comp.		285	285	285	283	285	282	282	282	282	283	2,834	283.4
47.	Max. Temperature, Fahr. deg.		2,090	2,075	2,050	2,045	2,050	1,970	1,970	2,000	2,000	2,000	20,250	2,025
48.	Energies.	Brake work, foot lbs.	2,460,000	2,440,000	2,380,000	2,290,000	2,320,000	2,210,000	2,250,000	2,280,000	2,210,000	2,360,000	23,200,000	2,320,000
49.		Brake work, foot lbs. per hour	14,750,000	14,650,000	14,300,000	13,750,000	13,900,000	13,250,000	13,500,000	13,700,000	13,250,000	14,150,000	139,200,000	13,920,000
50.		Brake horse-power	7.45	7.39	7.21	6.95	7.03	6.70	6.82	6.90	6.70	7.15	70.30	7.03
51.		B. T. U. equiv. to B. H. P.	3,160	3,130	3,060	2,950	2,980	2,840	2,890	2,930	2,840	3,030	29,810	2,981
52.		Indicated horse-power	8.25	8.35	8.45	7.60	7.75	7.93	8.22	8.80	8.06	8.44	81.85	8.185
53.		B. T. U. equiv. to I. H. P.	3,500	3,540	3,580	3,220	3,280	3,360	3,480	3,730	3,420	3,580	34,690	3,469
54.		Gas horse-power	42.5	41.2	41.7	40.3	40.3	38.6	35.8	37.8	38.0	39.4	395.6	39.56
55.		B. T. U. equiv. to Gas H. P. = H_1	18,000	17,550	17,700	17,100	17,100	16,400	15,200	16,000	16,100	16,700	167,850	16.785
56.		Heat supplied B. T. U. from indicator card = H'_1	6,230	5,960	6,250	5,860	6,350	6,040	5,990	6,250	6,160	6,180	61,270	6,127
57.		Heat extracted B. T. U. by observation = H_2	......	......	......	......	......	......	......	......	......	......	......	......
58.		Heat extracted B. T. U. from indicator card = H'_2	4,900	4,720	4,750	4,450	4,830	4,580	4,410	4,740	4,800	4,840	47,020	4,702
59.		I. H. P. — B. H. P.	0.80	0.96	1.24	0.65	0.72	1.23	1.40	1.90	1.36	1.29	11.55	1.155
60.	Throttling, cubic feet		.047	.048	.045	.042	.042	.034	.038	.037	.033	.042	.408	.0408
61	Throttling, per cent.		18.1	18.5	17.3	16.2	16.2	13.1	14.6	14.2	12.7	16.2	157.1	15.71
62	Work gained by complete expansion		......	......	......	......	......	......	......	......	......	......	......	......

		Number	1	2	3	4	5	6	7	8	9	10	Totals.	Average.
63.	Efficiencies.	Mech. eff. $= \frac{\text{Item 50}}{\text{Item 52}}$	.904	.885	.854	.915	.907	.846	.830	.785	.831	.848	8.605	.8605
64.		Thermal for B. H. P. $= \frac{\text{B. H. P.}}{H_1} = \frac{\text{Item 51}}{\text{Item 55}}$	.176	.178	.173	.173	.174	.173	.190	.183	.176	.181	1.777	.1777
65.		Thermal for B. H. P. $= \frac{\text{B. H. P.}}{H'_1} = \frac{\text{Item 51}}{\text{Item 56}}$	.507	.525	.490	.503	.469	.471	.483	.469	.461	.490	4.868	.4868
66.		Thermal for I. H. P. $= \frac{\text{I. H. P.}}{H_1} = \frac{\text{Item 53}}{\text{Item 55}}$	.194	.202	.202	.182	.192	.205	.228	.233	.212	.214	2.064	.2064
67.		Thermal for I. H. P. $= \frac{\text{I. H. P.}}{H'_1} = \frac{\text{Item 52}}{\text{Item 56}}$	.562	.594	.572	.549	.501	.557	.581	.596	.554	.579	5.645	.5645
68.		Thermal $= \frac{H_1 - H_2}{H_1}$												
69.		Thermal $= \frac{H'_1 - H'_2}{H'_1}$	.214	.208	.240	.240	.240	.242	.264	.241	.220	.217	2.326	.2326
70.		Thermal $= \frac{H'_1 - H_2}{H'_1}$												
71.	Stand'd Gas per hour.	Fuel per I. H. P.	20.2	19.5	19.3	20.8	20.4	19.0	17.2	16.8	18.5	18.4	190.1	19.01
72.		Fuel and igniter per I. H. P.												
73.		Fuel per B. H. P.	22.4	22.0	22.6	22.7	22.5	22.5	20.6	19.1	22.3	21.6	218.3	21.83
74.		Fuel and igniter per B. H. P.												
75.		Cost per I. H. P. per hour, cents, gas at $1.00 per 1,000 cubic feet	2.02	1.95	1.93	2.08	2.04	1.90	1.72	1.68	1.85	1.84	19.1	1.901

Heat Balance.	B. T. U.	Per cent.
Heat turned into work	3,469	20.6
Heat rejected into jacket water	7,209	43.0
Heat rejected in exhaust	4,772	28.5
Heat rejected in condensation and radiation	1,325	7.9

Analysis of fuel by..

Analysis of exhaust by..

Heat equivalent by analysis, B. T. U., to fuel..

" " " " " to exhaust..

Remarks.—

explanations of the method of working out a complete test if conducted on the plan outlined.

The titles following paragraphs are numbered to correspond to the items as they appear in the report.

Especial attention has been given to the arrangement of this report, the items appearing in the order in which they are most readily deduced; *i.e.*, with one or two possible minor exceptions, no solution is called for, for which the data have not already been supplied by the " log " or by a previous solution.

1. *Number.* 2. *Time Intervals.*

13. It is necessary to make frequent readings during the test, and item 1 corresponds to the numbers of these readings. What the interval between readings shall be is not material so that the period is sufficiently long to eliminate errors which might creep in from too brief intervals. Ten-minute intervals are recommended in case the total run is not over two or three hours. When the nature of the test is such that several hours are necessary for the determination of average results, or quantities of fuel used, the time intervals may be lengthened as desired, although thirty minutes should probably be the maximum time between readings. When more convenient the time interval will be designated by " int."

REVOLUTIONS AND EXPLOSIONS.

3. *Total Revolutions.*

14. Whenever possible a continuous speed counter should be used, and it is advantageous to obtain simultaneous records from two such counters.

It is best to check the readings during each interval by a hand indicator, in order that some record may be had in case of accident to the continuous recorders—especially if one recorder only be used.

The fluctuations in speed of a gas engine of the single cylinder type are so great and so varied that the readings of a hand speed counter taken for one minute are apt to be far from reliable, and dependence should be put upon them only in case of absolute necessity.

4. *Revolutions per Minute (Mean).*

15. The mean number of revolutions per minute is simply the total number of revolutions for the time interval divided by the number of minutes in that interval. The mean speed thus obtained is far more reliable than that obtained by the hand speed counter.

5. *Total Explosions.*

16. The general remarks regarding 3 apply. A continuous counter should be used whenever possible for determining the number of explosions. This can usually be done by connections to some stem or arm of the inlet valve, so that the counter is operated by the movements of this valve. Care should be taken to see that the ignitions are reliable and that every ignition gives an explosion.

Any method of simply counting the misses by sound or feeling, when they are frequent, is found to be absolutely unreliable.

6. *Explosions per Minute (Mean).*

17. These figures are obtained by dividing the total number of explosions for the time interval (item 5) by the number of minutes in that interval (item 2).

7. *Ratio of Revolutions to Explosions.*

18. This item gives a clear idea of the regularity of the explosions. In the single cylinder four-cycle engine making no misses, this ratio of the number of revolutions to the number of explosions would be 2.00. Any decrease in the number of explosions per minute would cause this ratio to increase, and a hasty glance at this item indicates at once the regularity of the explosions. In a single cylinder two-cycle engine the corresponding ratio is 1.00.

JACKET WATER.

8. *Weight in Pounds.* 9. *Weight in Pounds per Hour.*

19. The simplest method of weighing the jacket water is by means of two oil barrels, with proper outlet pipes, set upon plat-

Date, *March* 1, 1902.

Report of................"B"................................. ....Gas Engine Test.
Test No..
By...
Object...........*Efficiency, Proportions of Air to Gas*..............................

1.	Number	1	2	3	4	5	6	7	8	Totals.	Average.
2.	Time intervals, minutes	10	10	10	10	10	10	10	10	80	10
3.	Revolutions and Exps. — Total revolutions	3,005	3,006	3,002	3,012	3,015	3,012	3,007	3,005	24,065	3,008
4.	R. P. M. (mean)	300.6	300.6	300.2	301.2	301.5	301.2	300.7	300.5	2,406.5	300.8
5.	Total explosions	981	952	966	951	926	934	918	940	7,568	946
6.	Exps. P. M. (mean)	98.1	95.2	96.6	95.1	92.6	93.4	91.8	94.0	756.8	94.6
7.	Ratio of revs. to explosions	3.06	3.16	3.11	3.17	3.25	3.22	3.28	3.20	25.45	3.18
8.	Jacket Water. — Weight in lbs.	93.3	93.3	93.3	93.3	93.3	93.3	93.3	93.3	746.4	93.3
9.	Weight in lbs. per hour	560	560	560	560	560	560	560	560	4,480	560
10.	Temperature range	39.0	39.0	40.0	39.0	39.9	39.0	40.0	39.0	314.0	39.3
11.	Max. veloc., feet per second	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12.	Heat absorbed, B. T. U.	3,640	3,640	3,730	3,640	3,640	3,640	3,730	3,640	29,300	3,666
13.	Air. — Cubic feet	125.0	125.0	125.0	125.0	122.5	125.0	127.5	127.5	1,002.5	125.3
14.	Cubic feet per hour	750	750	750	750	735	750	765	765	6,015	752
15.	Temperature Fahr. deg.	87	87	87	87	87	87	87	87	.....	87
16.	Weight per cubic feet	.0725	.0725	.0725	.0725	.7025	.0725	.0725	.0725	.....	.0725
17.	Max. veloc. per second	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
18.	Specific heat, c_v	.1691	.1391	.1691	.1691	.1691	.1691	.1691	.1691	.....	.1691
19.	Fuel Gas. — Cubic feet or gals.	15.25	15.25	15.25	15.50	15.00	15.25	15.75	15.00	122.25	15.28
20.	Cubic feet per hour	91.5	91.5	91.5	93.0	90.0	91.5	94.5	90.0	733.5	91.7
	Gallons per hour	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
21.	Temperature Fahr. deg.	87	87	87	87	87	87	87	87	.....	87
22.	Weight per cubic feet	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Weight per gallon	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
23.	Max. veloc., ft. per second	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
24.	Specific heat, c_v	.1691	.1691	.1691	.1691	.1691	.1691	.1691	.1691	.....	.1691
25.	Cu. ft. Standard Gas per hour (60° Fahr., 14.7 lbs. pres.)	87.5	87.5	87.5	89.0	86.2	87.5	90.5	86.2	698.9	87.36
26.	Valve Index Reading. — Gas	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
27.	Air	.75	.75	.75	.75	.75	.75	.75	.75	.....	.75
28.	Values of n in Eq. $PV^n = P_1V_1^n$ for expansion curve	1.21	1.21	1.21	1.20	1.20	1.21	1.21	1.20	.....	1.21

		Number	1	2	3	4	5	6	7	8	Totals.	Average.
29.	Mixture.	Temperature Fahr. deg.	113	113	113	113	113	113	113	112	....	113
30.		Weight per cu. ft.	.0692	.0692	.0692	.0692	.0692	.0692	.0692	.0693	....	.0692
31.		Max. veloc., ft. per sec.	....	....	....	....	....	....	....	....	....	....
32.	Pressure from Indicator Cards.	Press. at end of comp.	86	91	89	89	91	91	91	91	719	89.89
33.		Max. pressure or pressure at beginning of expansion	230	254	242	252	238	238	254	233	1,941	242.6
34.		Press. at end of expansion	40	43	42	40	42	43	43	43	336	42
35.		Pressure, if expansion be carried to end of stroke	39	40	40	39	40	40.5	40.5	41.0	330.0	41.3
36.		M. E. P.	58.0	58.5	57.0	57.0	57.0	56.5	61.0	61.0	466.0	58.25
37.	Exhaust.	Temperature, Fahr. deg.	1,060	1,100	1,100	1,060	1,100	1,120	1,120	1,140	8,800	1,100
38.		Max. veloc., ft. per sec.	....	....	....	....	....	....	....	....	....	....
39.		Specific heat, c_v	.1691	.1691	.1691	.1691	.1691	.1691	.1691	.1691	....	.1691
40.	Ratios.	Air to gas, to	5.00	4.80	4.90	4.70	4.65	4.70	4.70	4.90	38.35	4.79
		Neutrals	1	1	1	1	1	1	1	1	8	1
			2.00	1.95	2.00	1.90	1.90	1.90	1.90	1.90	15.48	1.93
41.		Stroke to expansion	1.09	1.10	1.09	1.09	1.12	1.10	1.12	1.11	8.82	1.10
42.		Vols. v_2 to v_1	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	....	5.00
43.		Max. press. to M. E. P.	3.97	4.34	4.25	4.41	4.18	4.21	4.17	3.82	33.35	4.17
44.		Max. press. to comp. press.	2.68	2.79	2.72	2.83	2.62	2.64	2.79	2.56	21.63	2.70
45.	Value of R		.681	.681	.681	.681	.681	.681	.681	.682	....	.681
46.	Temperature Fahr. deg. at comp.		211	252	236	236	252	252	252	250	1,941	243
47.	Max. temperature, Fahr. deg.		1,610	1,600	1,470	1,550	1,580	1,700	1,600	1,600	12,710	1,589
48.	Energies.	Brake work, ft. lbs.	920,000	920,000	919,000	921,000	921,000	921,000	920,000	920,000	7,362,000	920,000
49.		Brake work, ft. lbs. per hr.	5,520,000	5,520,000	5,510,000	5,530,000	5,530,000	5,530,000	5,520,000	5,520,000	44,180,000	5,520,000
50.		B. H. P.	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79	22.32	2.79
51.		B. T. U. equiv. to B. H. P.	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	9,440	1,180
52.		I. H. P.	3.66	3.59	3.54	3.49	3.40	3.40	3.60	3.69	28.37	3.55
53.		B. T. U. equiv. to I. H. P.	1,550	1,520	1,500	1,480	1,440	1,440	1,530	1,560	12,020	1,503
54.		Gas H. P.	22.4	22.4	22.4	22.8	22.1	22.4	23.1	22.1	179.7	22.5
55.		B. T. U. equiv. to Gas H. P. $= H_1$	9,500	9,500	9,500	9,650	9,350	9,500	9,800	9,350	76,150	9,519
56.		Heat supplied B. T. U. from Indicator Card $= H_1'$	2,280	2,200	2,020	2,160	1,970	2,190	2,480	2,400	17,700	2,213
57.		Heat extracted B. T. U. by observation $= H_2$	....	....	....	....	....	....	....	....	....	....
58.		Heat extracted B. T. U. from Indicator Card $= H_2'$	1,460	1,480	1,480	1,420	1,420	1,480	1,680	1,770	12,190	1,524
59.		I. H. P. – B. H. P.	0.87	0.80	0.75	0.70	0.61	0.61	0.81	0.90	6.05	0.76
60.	Throttling, cubic feet		.0498	.0496	.0494	.0498	.0524	.0498	.0474	.0479	.3961	.0495
61.	Throttling, per cent		27.0	26.9	26.8	27.0	27.2	27.0	25.7	25.9	213.5	26.7

62. Work gained by complete expansion	....	....	....	....	....	....	....	....	....	....
63. Efficiencies. Mech. eff. $= \frac{\text{Item } 50}{\text{Item } 52}$	.763	.777	.788	.800	.821	.822	.775	.756	6.302	.788
64. Thermal for B. H. P. $= \frac{\text{B. H. B.}}{H_1} = \frac{\text{Item } 51}{\text{Item } 55}$	.124	.124	.124	.122	.126	.124	.120	.126	.990	.124
65. Thermal for B. H. P. $= \frac{\text{B. H. P.}}{H_1'} = \frac{\text{Item } 51}{\text{Item } 56}$	.517	.537	.584	.545	.599	.539	.476	.491	4.288	.536
66. Thermal for I. H. P. $= \frac{\text{I. H. P.}}{H_1} = \frac{\text{Item } 53}{\text{Item } 55}$	.163	.160	.158	.153	.154	.152	.156	.167	1.263	.158
67. Thermal for I. H. P. $= \frac{\text{I. H. P.}}{H_1'} = \frac{\text{Item } 53}{\text{Item } 56}$	.679	.691	.742	.685	.731	.657	.617	.650	5.452	.642
68. Thermal $= \frac{H_1 - H_2}{H_1}$	....	....	....	....	....	....	....	....	....	....
69. Thermal $= \frac{H_1' - H_2'}{H_1'}$	.359	.328	.268	.342	.279	.324	.322	.262	2.484	.311
70. Thermal $= \frac{H_1' - H_2}{H_1'}$	....	....	....	....	....	....	....	....	....	....
71. Stand. Gas per hour. Fuel per I. H. P.	23.9	24.4	24.7	25.5	25.3	25.7	25.7	23.4	198.6	24.8
72. Fuel and Igniter per I. H. P.	....	....	....	....	....	....	....	....	....	....
73. Fuel per B. H. P.	31.4	31.4	31.4	31.9	30.9	31.4	32.4	30.9	251.7	31.5
74. Fuel and Igniter per B. H P.	....	....	....	....	....	....	....	....	....	....
75. Cost per I. H. P. per hour, cents, gas at $1.00 per 1,000 cubic feet	2.39	2.44	2.47	2.55	2.53	2.57	2.57	2.34	19.86	2.48

Heat Balance.	B. T. U.	Per cent.
Heat turned into work	1,503	16.0
Heat rejected into jacket water	3,666	38.5
Heat rejected in exhaust	1,524	16.0
Heat rejected in condensation and radiation	2,826	29.5

Analysis of fuel by ....

Analysis of exhaust by ....

Heat equivalent by analysis, British Thermal Units, to fuel ....

" " " " " " " **to exhaust** ....

Remarks.—

form scales. The piping from the engine should be so constructed that the water may be fed into either barrel at will. It is hardly necessary to take the weight of the jacket water for each of the time intervals, provided the water flow has been carefully regulated before the test actually starts and the temperature of the feed water is found to be constant.

If the flow is maintained so nearly uniform that the fluctuations in temperature of the outlet water are not large—say for extreme range not over 15 degrees Fahr.—the total weight of water for the entire test may be recorded, and this result divided into equal proportions for the different runs.

20. Should the feed-water temperature show marked variations, which is likely to be the case if the water from the main passes through several buildings before reaching the engine, it should be weighed in small amounts and the weight and temperature entered on the "log."

The weight per hour is calculated directly from the values in item 8. In case of long runs it is well to determine the weight for each hour and to assign to each time interval its proportionate part.

10. *Temperature Range.*

21. Referring to items 10, 11, 12 of the "log," it is noticed that they are marked temperature of water entering, leaving, and barrel respectively. If the water used comes through a system of pipes running through warmed buildings, it is best, if possible, to allow the water to flow long enough to show fairly constant temperature before starting the test. This is especially necessary in winter when the water is taken from the city main—a difference of 45 degrees Fahr. is often observed under these conditions.

22. In cases where the weighing barrels are near the engine the temperature of the discharged water may be taken as it enters the barrel, which is often more convenient than to obtain the temperature just as the water leaves the engine. It has been found advantageous to keep a record of both when the conditions admit. In the tests shown no special attention was paid to the best temperature of the leaving jacket water. In general it seems to be the opinion that the hotter the water is allowed to get without injuring lubrication or giving premature ignition the better.

Some authorities give 160 degrees Fahr. as the best temperature for the discharge. Experiments seem to indicate that pressure in the water jacket is of little moment.

The range of temperature is the difference between the temperature of the leaving water and that of the entering.

11. *Maximum Velocity, Feet per Second.*

23. This has no direct bearing upon the test proper, but is inserted for use in making comparative tests of different engines, and for the determination of points of design of water inlets and outlets for the most effective results. The data collected would undoubtedly show variations depending upon the method of delivery, whether from natural circulation or forced.

12. *Heat Absorbed, B. T. U.*

24. The heat absorbed by the jacket water is a very large percentage of the entire heat supplied—often about 50 per cent. Since the specific heat of water is taken as unity, the calculation consists only in multiplying the number of pounds of water used during the interval by the range of temperature, this range of temperature being equal to the number of heat units absorbed per pound of water.

Data Given.	*Solution.*
s = specific heat of water = 1.	
t_r = temperature range.	
W = weight water for time interval.	$h_w = s \times t_r \times W$.
To Find—	
h_w = B. T. U. for the time interval.	
Examples.	
"*A*" Run No. 6:	
$s = 1.$	
$t_r = 72$ degrees.	
$W = 97$ pounds.	$h_w = 1 \times 72 \times 97 = 6{,}984$ B. T. U.
"*B*" Run No. 6:	
$s = 1.$	
$t_r = 39$ degrees.	
$W = 93.3$ pounds.	$h_w = 1 \times 39 \times 93.3 = 3{,}640$ B. T. U

AIR.

25. It is very essential that the quantity of air used be accurately measured, and the simplest, and usually most accessible, method is by means of a gas meter of sufficient size. The accuracy of this meter should be carefully determined. (For methods of calibration, see "Report of the Committee Appointed to Standardize a System of Testing Steam Engines.")

26. Even if the meter is carefully calibrated when working under suction, the readings will not be the same when the air enters under pressure, or vice versa. With the setting of the air valve as used in making test "B," the meter readings averaged for a given number of admissions 109.5 cubic feet when working under a pressure indicated by 2 inches of water, and 97.25 cubic feet when working under suction. The flow recorded by the meter was then 1.13 times as much when working under light pressure as when working under suction.

The meter through which the gas is measured works at all times under slight pressure, and for accurate determination of the proportions of air to gas the meter used for air measurement for the experiments upon which this paper is based was put under equal conditions by supplying air under pressure by means of an Ingersoll air compressor. In the absence of a compressor a blower may easily be arranged to accomplish the same result. The method of piping used is best explained by reference to the cut, Fig. 298.

27. *A* is the main compressed air line leading from the compressor to the air meter *B*. *C* is a relief tank filled with water to a depth corresponding to the head shown by the manometer attached to the gas pipe, and causing the flow of air through the meter to remain fairly constant. From *B* the air passes through the pipe *D*, directly to the engine save for the interposition of air bags *E* and *F* and an old muffler, used for the same purpose as the bags—namely, to reduce the variation in pressure of the air. At *H* is shown a manometer for determining the air pressure, and by means of the inlet valve *J* this pressure can be maintained the same as that shown by the gas manometer. By this method an accuracy in determining the proportions of air to gas was assured which otherwise could not be guaranteed.

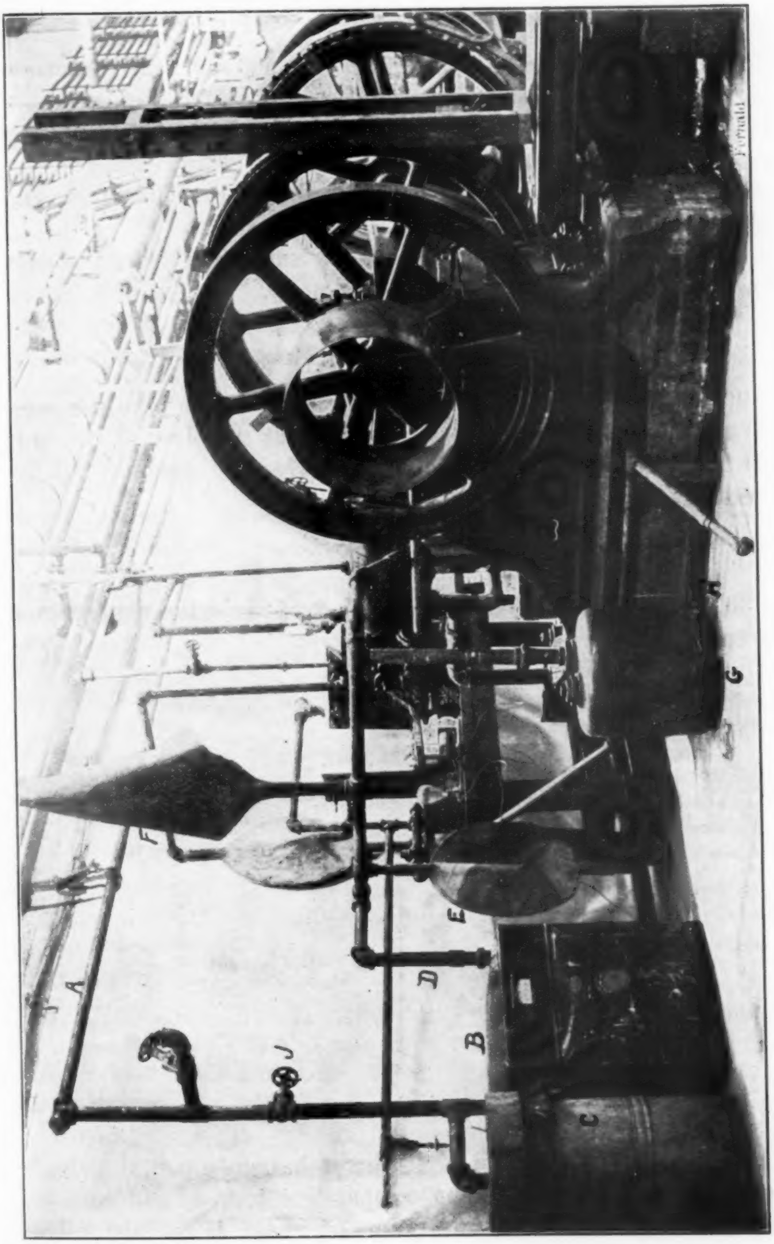

Fig. 298.

13. *Cubic Feet.* 14. *Cubic Feet per Hour.*

28. In reading the ordinary meter it is not sufficiently accurate to catch the readings by noting the positions of the index hands at the beginning and close of the time interval, but it is necessary to keep an observer at the meter and require the readings to be taken from the hand which indicates the single cubic feet, and whose complete revolution records 10 cubic feet.

The cubic feet per hour are readily calculated from the data for the given time interval.

15. *Temperature, Fahr.*

29. Under ordinary conditions it is sufficient to take the temperature of the air at the beginning and at the close of the test, but if the conditions are variable more frequent readings will be necessary.

16. *Weight per Cubic Foot.*

30. This weight is that of a cubic foot of air at the temperature given in item 15, and is found as follows:

Data Given.	*Solution.*
w_0 = weight cubic foot air at 32 degrees Fahr. = .0807 pound.	
$T_0 = 32° + 459° = 491°$ (absolute).	$\frac{w_1}{w_0} = \frac{T_0}{T_1}$ or $w_1 = .0807 \frac{491}{T_1}$.
T_1 = absolute temperature of air. = item 15 + 459°.	
To Find—	
w_1 = wgt. per cu. ft. at given temp.	
Examples.	
"*A*" Run No. 6: $T_1 = 86° + 459° = 545°$.	$w_1 = .0807 \frac{491}{545} = .0727$ pound.
"*B*" Run No. 6: $T_1 = 87° + 459° = 546°$.	$w_1 = .0807 \frac{491}{546} = .0725$ pound.

17. *Maximum Velocity in Feet per Second.*

31. Like item 11, this has no direct bearing upon the single test, but is for use in making comparative tests of different engines and for determination of points of design of air-inlet valves for the most effective results.

18. *Specific Heat, C_v.*

32. The specific heat of air at both constant pressure and constant volume may be found in any books on thermodynamics. The specific heat at constant volume, denoted by C_v, is the only value needed in this work—$C_v = .1691$.

FUEL.

33. The question of quantity of fuel used is the first to present itself, and the methods of determining this will depend entirely upon the kind of fuel. If coal is required the method of determining the amount is that usual in case of boiler tests, and is fully described in the *Transactions* of this Society, Vol. XXI., p. 34. The method used for ascertaining the amount of gas is by means of the standard gas meter. Methods of calibrating these meters are given in the "Report of the Committee appointed to Standardize a System of Testing Steam Engines." If oil is used it can easily be measured by means of calibrated tanks. For small engines using little oil, the tanks should be small in diameter, that the errors in measurement may be reduced as much as possible.

19. *Cubic Feet or Gallons.* 20. *Cubic Feet or Gallons per Hour.*

34. The method of measuring the fuel has already been explained. The quantities designated in item 19 refer to the amounts used for the given time interval, and if the fuel be gas, this would be the number of cubic feet as read directly from the meter.

If the fuel be oil the number of gallons for the period should be recorded.

21. *Temperature, Fahr.*

35. As in the case of air, it is usually sufficient to take the temperature of the gas at the beginning and at the close of the test, but if the conditions be variable more frequent readings will be necessary.

In case of engines which vaporize oil fuel before it enters the cylinder, this determination of temperatures is very difficult, if, indeed, possible. There are many forms of carburettors, and the temperatures of vaporization are found to vary greatly.

Further developments may determine the desired method of making reliable observations of the temperature of this type of fuel.

22. *Weight per Cubic Foot or Gallon.*

36. In case the fuel be gas, it is not always convenient to obtain the weight per cubic foot. If the temperatures of the air and gas be the same, this is hardly necessary, and even when these temperatures be different the necessity of knowing this weight is not sufficient to warrant great inconvenience or expense in obtaining it.

23. *Maximum Velocity in Feet per Second.*

37. As in items 11 and 17, this has no direct bearing upon the single test, but is for use in making comparative tests of different engines and for determination of points of design.

24. *Specific Heat, C_v.*

38. Unless it is convenient to ascertain accurately the desired specific heat of the gas used, no serious error results from taking the specific heat at constant volume the same as for air; namely, $C_v = .1691$.

25. *Cubic Feet of Standard Gas per Hour* (60 *Degrees Fahr.*, 14.7 *Pounds Pressure*).

39. The general standard recommended seems to indicate for "Standard Gas" the conditions given; namely, a temperature of 60 degrees Fahr. and a pressure corresponding to the usual atmospheric pressure. It is hardly necessary to make corrections for barometric readings, as the total possible variation is slight, and considering all other sources of error it is a question whether this supposed degree of refinement adds to the accuracy of the results.

Atmospheric pressure will then be understood to mean as indicated, 14.7 pounds per square inch.

40. The pressure shown by the manometer attached to the gas pipe might also be neglected in making the computations, as its effect upon the result is hardly perceptible. It has, however, been considered in the illustrative problems, the value having been recorded in the log of the test, thus adding no labor to the computations. It may be of interest to note that the total effect of neglect-

ing both the changes in barometric conditions and in the pressures shown by gas mains, when these changes are taken at a maximum, is less than one-half of one per cent. of the number of cubic feet per hour.

Data Given.	*Solution.*
v_g = cu. ft. of gas per hour at t_g ° F.	
T_g = absolute temp. of gas = t_g ° + 459°.	
p_g = pressure under which gas is flowing.	$\frac{v_s}{v_g} = \frac{p_g T_s}{p_0 T_g}$
= 14.7 lbs. + pressure shown by manometer.	
T_s = 60° + 459° = 519° F., absolute temp. of standard gas.	$v_s = v_g \frac{p_g T_s}{p_0 T_g}$
p_0 = atmospheric pressure. = 14.7 lbs. per sq. in.	
To Find—	
v_s = cu. ft. standard gas per hour.	
Examples.	
"A" Run No. 6: v_g = 157.5 cu. ft. T_g = 86° + 459° = 545°. p_g = 14.7 + .1 = 14.8 lbs. per sq. in.	$v_s = 157.5 \frac{14.8 \times 519}{14.7 \times 545} = 151$ cu. ft.
"B" Run No. 6: v_g = 91.5 cu. ft. T_g = 87° + 459° = 546°. p_g = 14.7 + .1 = 14.8 lbs. per sq. in.	$v_s = 91.5 \frac{14.8 \times 519}{14.7 \times 546} = 87.5$ cu. ft.

VALVE INDEX READING.

26. *Gas.* 27. *Air.*

41. This refers to the setting of the graduated inlet valves, and has no direct bearing on the single test, but is of value in making comparative tests.

28. *Value of n in* $PV^n = P_1 V_1^n$ *for Expansion Curve.*

42. At this point in the analysis, more or less difficulty is likely to be encountered. The necessity of carefully working out this value of n for each card may not at first seem apparent, but slight investigation shows it to be of great importance.

It is not unnatural to assume that the expansion curve and the compression curve, as given by the indicator card, follow very closely the adiabatic law.

Working upon this supposition leads in many cases to a network of difficulties, from which it is not easy to free one's self. For example, a case that came to the attention of the writer was as follows: In making a preliminary test, owing to the fact that it was inconvenient to determine the exact clearance volume of the engine, instructions were given to work out the clearance from the indicator card. The method is quickly shown by the following deductions and reference to the card shown in Fig. 299.

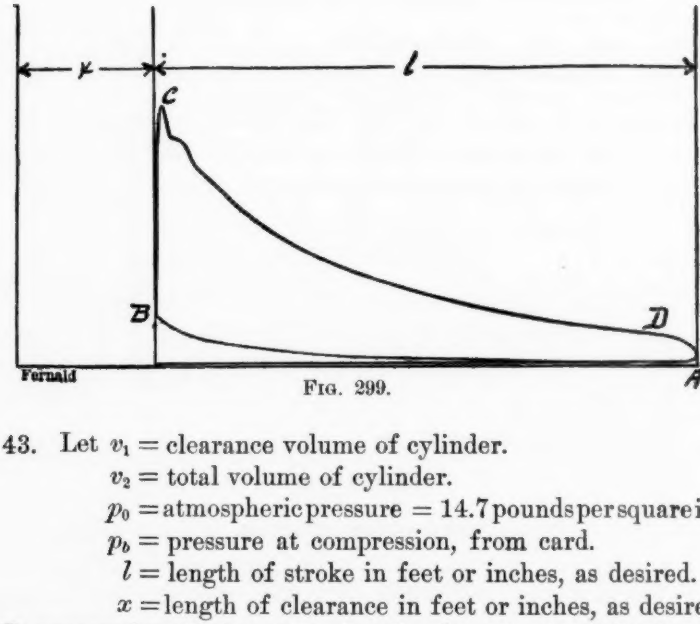

FIG. 299.

43. Let v_1 = clearance volume of cylinder.

v_2 = total volume of cylinder.

p_0 = atmospheric pressure = 14.7 pounds per square in.

p_b = pressure at compression, from card.

l = length of stroke in feet or inches, as desired.

x = length of clearance in feet or inches, as desired.

It appeared a simple matter to solve for x in the following formulas: $\frac{p_b}{p_0} = \left(\frac{v_2}{v}\right)^n$ or $\left(\frac{p_b}{p_0}\right)^{\frac{1}{n}} = \frac{v_2}{v_1}$ which readily reduces to $\left(\frac{p_b}{14.7}\right)^{\frac{1}{n}} = \frac{x+l}{x}$, on the assumption that n for the compression curve was 1.41 or $\frac{1}{n} = .71$.

This gave an excessively large clearance volume, and the values of n worked out for the expansion curve varied greatly, but the best value seemed to be about 1.7, although the necessity of carefully determining the value of this exponent for each card was at once apparent.

Maximum temperatures computed on the basis of the value of n above proved to be in the neighborhood of 4,000 degrees Fahr. This surprisingly large value of n, together with the excessively high temperatures, led at once to a careful study of the problem, for it was apparent that no assumptions regarding the laws of expansion could safely be made. The clearance volume was at once determined by the usual method of filling the space with water. It may be well here to emphasize the necessity of great care in releasing all air from this clearance space as the water is poured in.

44. The values of n now deduced from the expansion curve for

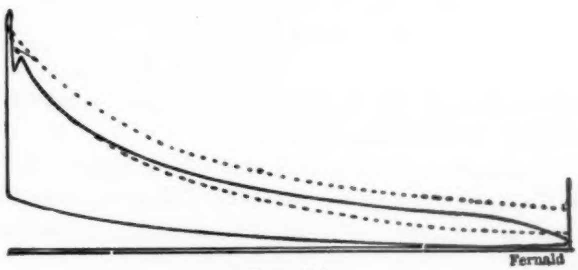

FIG. 300.

the diagrams taken from this particular engine showed for portions of the curve values as surprisingly low as those first determined were high. It was found that this exponent varied greatly in different parts of the curve for the diagrams taken from this engine, but no satisfactory law of variation could be determined. With the high pressure spring used in the indicator it was very difficult to obtain accurate values from the cards secured.

45. With a 240-lb. spring, which was the one used, each .01 of an inch in vertical measurement corresponds to 2.4 lbs. pressure, and errors resulting from irregularities in the curve, variations in the width of line, and mistakes in observation render it almost impossible to work with the degree of accuracy desired. In Fig. 300 is shown one of the cards taken in making test "A." The upper dotted curve represents isothermal expansion and the lower dotted curve adiabatic expansion.

It is seen at a glance that early in the expansion the full line follows very closely the adiabatic curve and then approaches nearer and nearer the isothermal as the expansion continues. The value of n which has been chosen for recording in item 28 is the value

found for the latter part of the expansion, as this value is the one most needed in computations that follow. Owing to the fluctuations in many curves near the beginning of expansion, it has been

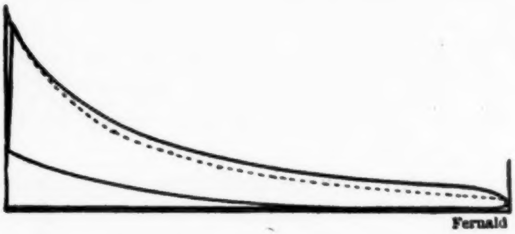

FIG. 301.

found extremely difficult to obtain values that could be regarded as reliable for the pressures desired.

46. The card shown in Fig. 301 was taken during test "B," and although the expansion curve seems to follow the adiabatic more closely than in Fig. 300, yet there is considerable variation even in this case.

Repeated calculations showed the best value of n for the expan-

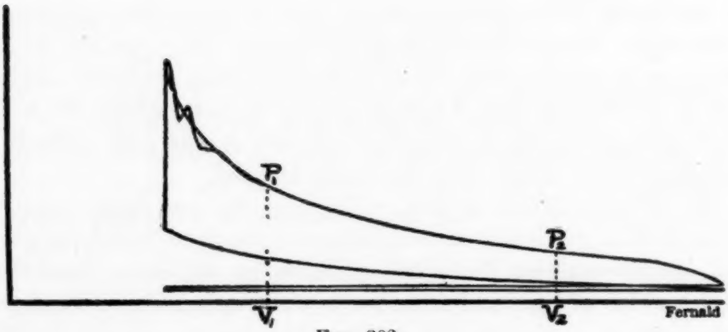

FIG. 302.

sion curve for the cards of test "A" to be 1.14 and for test "B" 1.21 or 1.20.

The mathematical work involved in obtaining n is explained below:

Data Given.

Any corresponding values of pressure and volume obtained from the indicator card. Great care should be exercised in the selection of these points if the equation of the expansion curve is found to vary for different portions of the curve. All measurements must, of course, be made from the zero of volumes and zero of pressures.

V_1 = some assumed volume.
P_1 = pressure corresponding to V_1.
V_2 = another assumed volume.
P_2 = pressure corresponding to V_2.

Examples.

"A" Run No. 6 (For this problem the values of P and V are selected as shown in Fig. 302):

$V_1 = 6.2 \qquad P_1 = 141$
$V_2 = 12.2 \qquad P_2 = 65$

"B" Run No. 6:

$V_1 = 5 \qquad P_1 = 108$
$V_2 = 8 \qquad P_2 = 61$

Solution.

$$P_1 V_1^n = P_2 V_2^n$$

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^n$$

$$\log. \frac{P_1}{P_2} = n \log. \frac{V_2}{V_1}$$

$$n = \frac{\log. \frac{P_1}{P_2}}{\log. \frac{V_2}{V_1}}$$

$$\text{or,} \quad n = \frac{\log. P_1 - \log. P_2}{\log. V_2 - \log. V_1}$$

$$\begin{array}{ll} \log. P_1 = 2.14922 & \log. V_2 = 1.08636 \\ \log. P_2 = \underline{1.81291} & \log. V_1 = \underline{0.79239} \\ \ .33631 & \ .29397 \end{array}$$

$$n = \frac{.33631}{.29397} = 1.14$$

Solving by the first formula,

$$n = \frac{\log. \frac{P_1}{P_2}}{\log. \frac{V_2}{V_1}},$$

shortens the work if a slide rule is used

$$\frac{P_1}{P_2} = \frac{108}{61} = 1.77, \ \log. = 0.24797$$

$$\frac{V_2}{V_1} = \frac{8}{5} = 1.6, \ \log. = 0.20412$$

$$n = \frac{.24797}{.20412} = 1.21$$

47. The following values of n were worked out with great care from a series of volumes and corresponding pressures, and show the fluctuations to which this calculation is subject. The values are arranged as derived in regular order from left to right, but do not include values for very small volumes, as the variations in pressure were too great to enable any reliable readings. As derived from the card selected n = 1.21, 1.12, 1.14, 1.16, 1.13, 1.135, 1.12, 1.10, 1.10 1.12, 1.15, 1.15, 1.15 1.14, 1.16, 1.13.

A variation of a single pound in the pressure, or, in some cases, of one-half pound, determines the accuracy of the deduction, but with such high pressure springs this degree of refinement is impossible. It was noted in several cases that the value of n for the

compression curve was slightly higher than for the expansion curve.

A simple method of ascertaining whether this exponent is the same for corresponding compression and expansion curves is as follows:

48. Locate a series of different volumes upon the card in question and determine the corresponding pressures for both the compression and expansion curves. If the ratio of the corresponding pressures of the two curves remains constant, the exponents for the equations of the two curves will be found to be identical.

Let V_1 and V_2 = two volumes chosen, as in Fig. 302. For the expansion curve the two pressures = P_1 and P_2 and for the compression curve the pressures corresponding to the same volumes = P_3 and P_4. Let x be the exponent in the equation of the expansion curve, viz: $P_1 V_1^x = P_2 V_2^x$ and let y be the corresponding exponent for the compression curve, or $P_3 V_1^y = P_4 V_2^y$

By division $\dfrac{P_1 V_1^x}{P_3 V_1^y} = \dfrac{P_2 V_2^x}{P_4 V_2^y}$. If now the exponents for the two curves be the same, *i. e.*, if $y = x$ then $\dfrac{P_1 V_1^x}{P_3 V_1^x} = \dfrac{P_2 V_2^x}{P_4 V_2^x}$ or $\dfrac{P_1}{P_3} = \dfrac{P_2}{P_4}$.

MIXTURE.

29. *Temperature, Degrees Fahr.*

49. One of the longest deductions, as well as one of the most difficult, but at the same time of great importance, is that of obtaining the temperature of the mixture in the cylinder, composed of air, gas, and exhaust gases, or neutrals, as the last are sometimes called. The problem involves the larger portion of all the readings made during the test, as well as the careful determination of the temperature of the exhaust gases.

The mixture passes through a wide range of temperatures, and the only one which can be determined is that of the exhaust. This has proved to be of such great importance and so little seems to be known regarding the determination of this factor, that much of the time devoted to the subject of gas engine testing was given to the solution of this problem.

Very few methods for measuring this temperature seem to exist, and these are either too inaccurate to be of any value, or in cases where the results seem to indicate accuracy, the method is too

complicated or the apparatus too expensive for use under ordinary circumstances.

50. Even the committee appointed by the Society to "Standardize a System of Testing Steam Engines" avoids the question entirely. This committee speaks of the "observed temperature of the exhaust gases," but in no way is any intimation given of a method of observation.

A simple device for determining these temperatures seems so necessary that it is deemed wise to give a complete description of the apparatus used by the writer, in a separate paper entitled, "A Method of Determining the Temperatures of Exhaust Gases," and presented as paper No. 949 at this meeting.

To avoid confusion, the computations for determining the temperature of the mixture will be divided into two parts.

PART I.

51. To determine the combined volumes of air and gas per stroke and the temperature of the same:

Case 1. When the temperatures of the incoming air and gas are equal:

Data Given.

Mins. = No. miuutes in time interval.

g = gas per min. = $\dfrac{\text{item 19}}{\text{mins.}}$

a = air per min. = $\dfrac{\text{item 13}}{\text{mins.}}$

T_2 = absolute temp. gas.
= T_1 absolute temp. air.
= item. 21 or 15 + 459°.

Ex. P. M. = explosions p. min. = item 6.

R. P. M. = revolutions p. min. = item 4.

Ms. P. M. = explosions missed per min.
= ½ *R. P. M.* – *Ex. P. M.* for single cylinder four-cycle engine.

To Find—

v' = cu. ft. gas per explosion at T_1.

v'' = cu. ft. air per explosion at T_2.

T_{ag} = absolute temperature in *F.*° resulting from combining air and gas = $T_1 = T_2$.

v_{ag} = combined vol. in cu. ft. of air and gas per explosion at T_{ag}.

Solution.

$$v' = \frac{g}{Ex.\ P.\ M.}$$

$$v'' = \frac{a - v'\,[Ms.\ P.\ M.]}{[\tfrac{1}{2}\ R.\ P.\ M.]}$$

Since $T_{ag} = T_1 = T_2$,

$$v_{ag} = v' + v''.$$

Examples.

"A" Run No. 6:

$$g = \frac{26.25}{10} = 2.625 \text{ cu. ft.}$$

$$a = \frac{194}{10} = 19.4 \text{ cu. ft.}$$

$$T_1 = T_2 = 86^\circ + 459^\circ = 545^\circ.$$

$Ex.\ P.\ M. = 133.9.$

$R.\ P.\ M. = 267.9.$

$Ms.\ P.\ M. = 0.$

$$v' = \frac{2.625}{133.9} = .0196 \text{ cu. ft.}$$

$$v'' = \frac{19.4 - .0196 \times 0}{133.9} = 145 \text{ cu. ft.}$$

And since $T_{ag} = T_1 = T_2$.

$$v_{ag} = v' + v'' = .1646 \text{ cu. ft.}$$

"B" Run. No. 6:

$$g = \frac{15.25}{10} = 1.525 \text{ cu. ft.}$$

$$a = \frac{125.0}{10} = 12.5 \text{ cu. ft.}$$

$$T_1 = T_2 = 87^\circ + 459^\circ = 546^\circ.$$

$Ex.\ P.\ M. = 93.4.$

$R.\ P.\ M. = 301.2.$

$Ms.\ P.\ M. = 57.2.$

$$v' = \frac{1.525}{93.4} = .0163 \text{ cu. ft.}$$

$$v'' = \frac{12.5 - .0163 \times 57.2}{150.6} = .0769 \text{ cu. ft.}$$

And since $T_{ag} = T_1 = T_2 = 546^\circ$,

$$v_{ag} - v' + v'' = .0932 \text{ cu. ft.}$$

Case 2. When the temperatures of the incoming air and gas are different:

Data Given.

$Mins.$ = No. minutes in time interval.

g = gas per min. $= \dfrac{\text{item 19}}{\text{mins.}}$

a = air per min. $= \dfrac{\text{item 13}}{\text{mins.}}$

T_1 = absolute temp. air in F.°.
= item 15 + 459°.

T_2 = absolute temp. gas in F°.
= item 21 + 459°.

$Ex.\ P.\ M.$ = explosions per minute = item 6.

$R.\ P.\ M.$ = revolutions per minute = item 4.

$Ms.\ P.\ M.$ = explosions missed per min.
$= \frac{1}{2}\ R.\ P.\ M. - Ex.\ P.\ M.$ for single cylinder four-cycle engine.

w_1 = wgt. per cu. ft. air at T_1 = item 16.

w_0 = wgt. per cu. ft. air at 32° F. = .0807 lb.

T_0 = absolute temp. corresponding to 32° F. = 491°.

v' = cu. ft. gas per explosion at T_2 } as found under Case 1.
v'' = cu. ft. air per explosion at T_1 }

Solution.

The general equation from which T_{ag} can be computed is

$$c_p\,(T_1 - T_{ag})\,w_a = c_p\,(T_{ag} - T_2)w_g.$$

It is now necessary to find w_a and w_g.

If it is not convenient to obtain the weight of gas per cubic foot, the best that can be done is to take the weight of gas the same as that of air at the same temperature. The error involved by so doing is not serious.

Then
$$w_2 = w_0\,\frac{T_0}{T_2}$$

$$w_a = w_1 \times v''$$
$$w_g = w_2 \times v'$$

T_{ag} can now be computed from the equation above.

$$v''' = v'\,\frac{T_{ag}}{T_2}$$

$$v'''' = v''\,\frac{T_{ag}}{T_1}$$

$$v_{ag} = v''' + v''''.$$

C_p = specific heat of air at constant pressure.

To Find—

w_3 = wgt. cu. ft. gas at T_2.

w_a = wgt. of air per explosion at T_1.

w_g = wgt. of gas per explosion at T_2.

T_{ag} = absolute temp. in F.° resulting from combining air at T_1 and gas at T_2.

v''' = cu. ft. gas per explosion at T_{ag}.

v'''' = cu. ft. air per explosion at T_{ag}.

v_{ag} = combined vol. in cu. ft. of air and gas per explosion at T_{ag}.

Part II.

52. The combined volumes of air and gas used per explosion, together with the temperature of the same, having been computed as indicated in Part I. of this section, the problem is now to determine the temperature of the final mixture in the cylinder after the air and gas have united with the exhaust gases in the clearance space—unless the engine is of the scavenging type.

It is to be noticed that if the governor is of the hit or miss type, the exhaust stroke following a miss corresponds to a scavenging stroke.

Data Given.

Assume the weight of the final mixture equal to the weight of air at the same temperature. Assume the specific heats of the different mixtures the same as for air.

w_0 = weight cu. ft. air at 32° F. = .0807 lb.

T_0 = absolute temp. corresponding to 32° F. = 491°.

C_p = specific heat air at constant pressure.

= specific heat air and gas at constant pressure.

= specific heat final mixture at constant pressure.

T_{ag} = absolute temp. of air and gas entering cylinder as computed in Part I.

Solution.

$$w_3 = w_0 \frac{T_0}{T_{ag}}$$

$$w_4 = w_0 \frac{T_0}{T_e}$$

$$w_{ag} = w_3 \times v_{ag}$$

$$w_e = w_4 \times v_5$$

T_m can now be computed from the equation

$$c_p (T_m - T_{ag})\, w_{ag} = c_p\, (T_e - T_m)\, w_e$$

$$T_m = \frac{T_{ag}\, w_{ag} + T_e\, w_e}{w_{ag} + w_e}$$

v_{ag} = cu. ft. air and gas at T_{ag} as computed in Part I.

T_e = absolute temp. exhaust gases at atmospheric pressure.

= temp. observed and recorded in item 14 of log + 459°.

v_b = vol. of clearance in cu. ft.

To Find—

w_3 = weight cu. ft. of air and gas at T_{ag}.

w_4 = weight cu. ft. of exhaust gases at T_e.

w_{ag} = weight of air and gas per explosion at T_{ag}.

w_e = weight of exhaust gases per explosion at T_e.

T_m = absolute temp. of final mixture in cylinder.

$T_m - 459° =$ F.° as in item 29.

Examples.

"A" Run No. 6:

$w_0 = .0807$ lb.

$T_0 = 32° + 459° = 491°$.

$T = T_1 = T_2 = 86° + 459° = 545°$.

$v_{ag} = .1646$ cu. ft. as computed in Part I.

$T = 180° + 459° = 639°$ by observation.

$v_b = .055$ cu. ft. by measurement.

$$w_3 = .0807 \frac{491}{545} = .0727 \text{ lb.}$$

$$w_4 = .0807 \frac{491}{639} = .0621 \text{ lb.}$$

$$w_{ag} = .0727 \times .1646 = .0120 \text{ lb.}$$

$$w_e = .0621 \times .055 = .00342 \text{ lb.}$$

$$(T_m - 545)\ .012 = (639 - T_m)\ .00342$$

$$.01542\ T_m = 8.72$$

$$T_m = 565°$$

$$565° - 459° = 106° \text{ F.}$$

"B" Run No. 6:

$w_0 = .0807$ lb.

$T_0 = 32° + 459° = 491°$.

$T_{ag} = 87° + 459° = 546°$.

$v_{ag} = .0932$ cu. ft. as computed in Part I.

$T' = 188° + 459° = 647°$ by observation.

$v_b = .037$ cu. ft. by measurement.

$$w_3 = .0807 \frac{491}{546} = .0725 \text{ lb.}$$

$$w_4 = .0807 \frac{491}{647} = .0612 \text{ lb.}$$

$$w_{ag} = .0725 \times .0932 = .00676 \text{ lb.}$$

$$w_e = .0612 \times .037 = .00226 \text{ lb.}$$

$$(T_m - 546)\ .00676 = (647 - T_m)\ .00226$$

$$.00902\ T_m = 5.15$$

$$T_m = 572°$$

$$572° - 459° = 113° \text{ F.}$$

30. *Weight per Cubic Foot.*

53. *Data Given.*

w_0 = weight cu. ft. air at 32° F. = .0807.

T_0 = absolute temp. corresponding to 32° F. = 491°.

T_m = absolute temp. of mixture as computed in 29.

Solution.

$$w_5 = w_0 \frac{T_0}{T_m}$$

$$= .0807 \frac{491}{T_m}$$

To Find—	
w_5 = weight cu. ft. of mixture at T_m.	
Examples.	
"A" Run No. 6: $T_m = 565°$ from 29.	$w_5 = .0807 \frac{491}{565} = .0701$ lb.
"B" Run No. 6: $T_m = 572°$ from 29.	$w_5 = .0807 \frac{491}{572} = .0692$ lb.

31. *Maximum Velocity, Feet per Second.*

54. This velocity refers strictly to the rate of flow of the entering mixture of air and gas and not to the final mixture in the cyl-

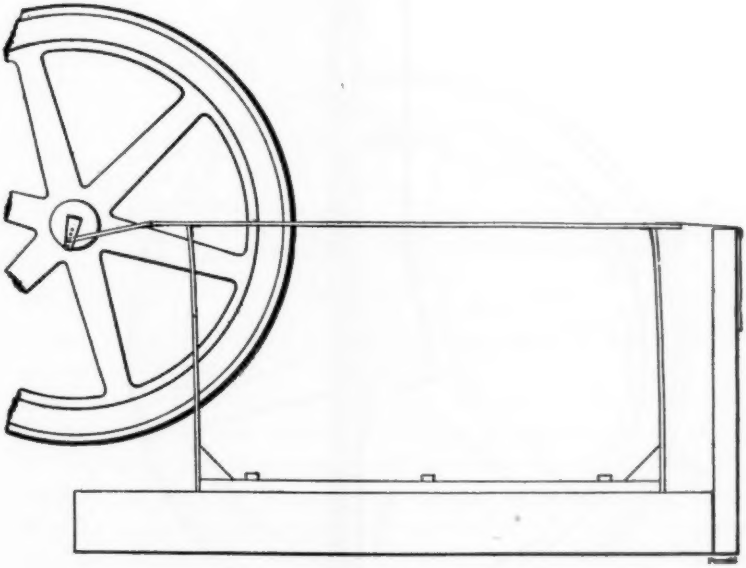

FIG. 303.

inder. As in items 11, 17, 23, this maximum velocity is for use in making comparative tests only, and for determining points of design.

PRESSURE FROM INDICATOR CARDS.

55. The indicator card bears such an important relation to the test that great care should be taken to have the reducing motion, indicator, and all connections properly adjusted. Owing to the ex-

treme maximum pressure resulting from the explosion, the ordinary steam engine indicator is far too delicate for service. A

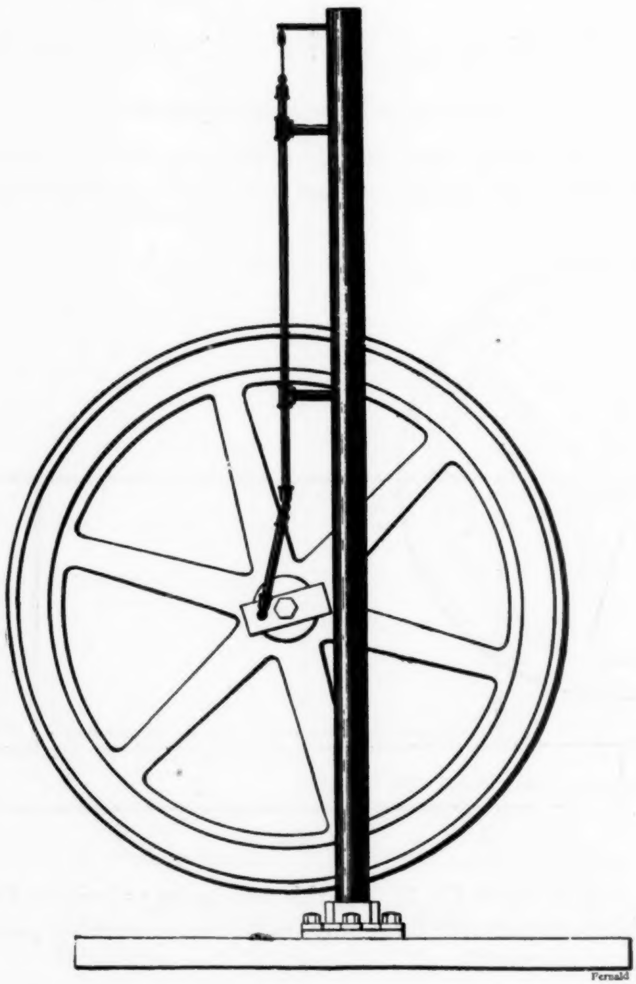

FIG. 304.

special gas engine indicator with a small piston, strong spring, strengthened pencil arm and carefully adjusted pin connections is very necessary. It is well at all times to keep the pipe leading to

the indicator packed with cotton waste saturated frequently with water, to prevent the temperature of the indicator from becoming excessive and thus rendering it unreliable. When it can be easily done it is an excellent plan to jacket this connection.

Care should always be taken to record on the log sheet the scale of the spring used. Never trust to memory for this or any other fact.

When the compression cylinder is independent, the scale of the spring used for the cards taken from this cylinder should also be recorded on the log sheet, and the card so taken should be reduced to the same scale and combined with the power card.

For convenience in making this combination care should be exercised in adjusting the reducing motion to insure the same length of card in both cases.

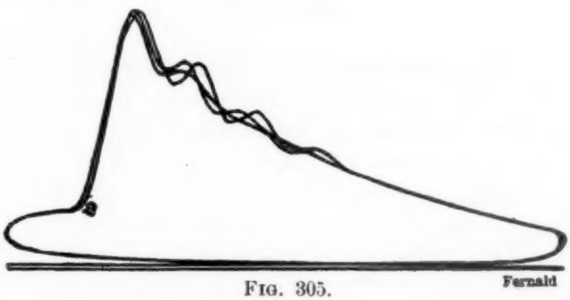

FIG. 305.

56. The reducing motion may be any one of the forms usually constructed for such purposes, provided it can be readily attached.

The lack of a cross-head and the enclosed crank case on the modern gas engine prevent the use of some reducing motions. The forms shown have been used with perfect satisfaction upon the engines tested at Columbia, that shown in Fig. 303, for horizontal engines, and that in Fig. 304 for vertical. They are especially recommended for cheapness and for the ease with which they can be constructed on the grounds.

The utmost care should be exercised in adjusting the reducing motion. It is not sufficiently accurate to regulate merely by the eye, but sample cards should be taken and adjustments made until the motion is correct.

57. Fig. 305 shows the result when the true position of the reducing motion is seriously disturbed. The engine appears to continue compressing long after the piston has started toward the

crank end of the cylinder, the maximum compression pressure being shown at S, at which point the ignition takes place. The series of explosions which follow in rapid succession when the igni-

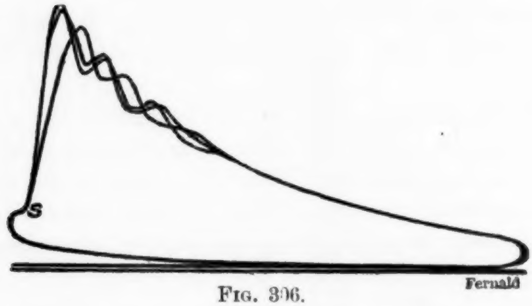

Fig. 306.

tion is early, as is the case in this instance, appear seriously distorted, continuing apparently through the greater part of the stroke, an effect produced by the relatively high speed of the in-

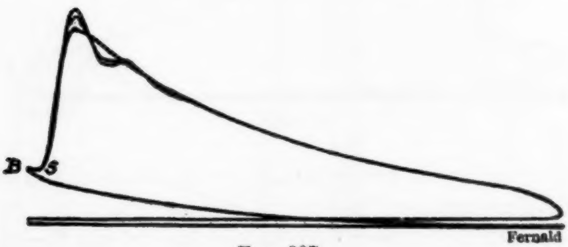

Fig. 307.

dicator drum. With a card so seriously distorted, the error is quickly perceived, but when the error is as shown in Fig. 306, the difficulty is not quite as apparent.

A casual glance might lead one to suppose this form of card

Fig. 308.

due to late ignition, but closer examination will show the compression pressure to be steadily rising to the point S. This indicates that the reducing motion is still incorrectly adjusted.

When a similar effect is produced by late ignition only and the reducing motion is properly set, the line from B to S is horizontal or even depressed, as shown in Figs. 307 and 308.

58. Fig. 309 shows a case which is approaching the limiting position of the reducing motion, but close scrutiny shows the compression to continue slightly after the engine has passed its dead-

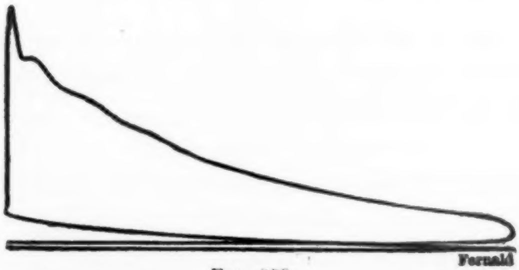

Fig. 309.

centre. The early ignition shown in Fig. 309 tends to conceal the fault due to the reducing motion, and in cases where the ignition is premature great care should be taken to secure the proper regulation before ignition is set too early.

In Fig. 310 is shown the typical card with early ignition and the reducing motion properly set so that the maximum compression as shown by the card corresponds to the position of the inner dead-centre of the engine.

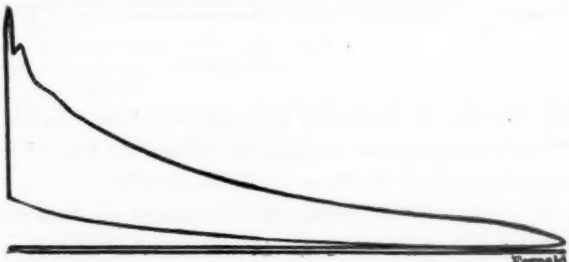

Fig. 310.

Errors of the kind just described, although apparently slight in the limiting cases, should be guarded against, as the deductions of the entire test may be seriously affected by such oversights.

To insure accuracy it is better to establish the line LC, Fig. 311,

by allowing the indicator drum to remain stationary while the indicator cock is opened and the pencil moved up and down, than simply to draw LC at right angles to the atmospheric line. The lines of zero volume and zero pressure can then be drawn parallel to LC and the atmospheric line respectively.

32. *Pressure at End of Compression.*

59. Referring to the diagram (Fig. 311), the absolute compression pressure is represented by the distance LB, measured from the line of zero pressures.

33. *Maximum Pressure, or Pressure at the Beginning of Expansion.*

60. Some care is necessary in determining this value in cases where the diagram shows a series of explosive waves. In Fig. 311

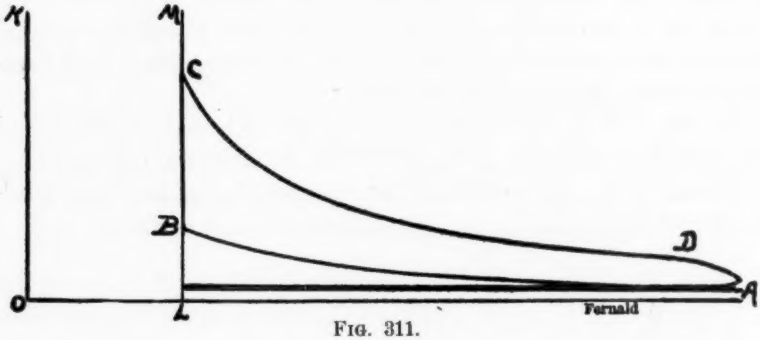

FIG. 311.

the distance measured from the zero pressure line to the point C is easily determined as the maximum pressure, but in cases like Fig. 312 the possibility of error is much greater.

By marking the centre points of the series of explosion peaks and continuing the expansion line from some lower point in the curve through these points, a fairly accurate determination of the maximum pressure may be made.

If the value of n determined in 28 be regarded as accurate, a very good check may be had upon the maximum pressure obtained graphically, by computing the pressure from the equation of the curve.

34. *Pressure at End of Expansion.*

61. The determination of the end of expansion, or point of release, is often attended by some difficulty, as the point is not marked by any sudden change in the direction of the expansion curve, but is at the point of inflexion, D (Fig. 312). As in the other cases the pressure is measured from the zero lines of pressures.

35. *Pressure if Expansion were Carried to End of Stroke.*

62. This value is readily obtained from the equation of the expansion curve, the value of the exponent n having been computed in 28. If the expansion were thus continued it would give the point H, as shown in Fig. 312. The pressure corresponding to the point H is deduced as follows:

Data Given.

V_1 = volume at some point of the card.
P_1 = pressure corresponding to V_1.
n = value deduced in 28.
V_2 = total volume of cylinder.

To Find—

P_2 = pressure corresponding to V_2; *i. e.*, if expansion continued to H.

Solution.

$$P_1 V_1^n = P_2 V_2^n$$

$$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^n$$

$$\log. P_2 = \log. P_1 + n \log. \frac{V_1}{V_2}$$

The volumes being used as a ratio, the piston area may be omitted, the ratio of lengths being the same as the ratio of volumes, as is customary in working with indicator cards.

Examples.

"A" Run No. 6:
V_1 = 12.2 for one point of card.
P_1 = 65 pounds pressure corresponding to V_1.
n = 1.14 from item 28.
V_2 = 15.9 for total volume of cylinder.

$$P_2 = 65 \left(\frac{12.2}{15.9}\right)^{1.14}$$

$$1.14 \log. \frac{12.2}{15.9} = 9.86885 - 10$$
$$\log. 65 = 1.81291$$
$$\log. P_2 = 1.68176$$
$$P_2 = 48$$

"B" Run No. 6:
V_1 = 8 for one point of card.
P_1 = 61 pounds pressure corresponding to V_1.
n = 1.21 from item 28.
V_2 = 11.25 for total volume of cylinder.

$$P_2 = 61 \left(\frac{8}{11.25}\right)^{1.21}$$

$$1.21 \log. \frac{8}{11.25} = 9.82076 - 10$$
$$\log. 61 = 1.78533$$
$$\log. P_2 = 1.60609$$
$$P_2 = 40.5$$

36. *Mean Effective Pressure.*

63. It is necessary to determine the area of the diagram, and for this purpose the planimeter should be used, although other methods will answer, but are very tedious and not as accurate. The

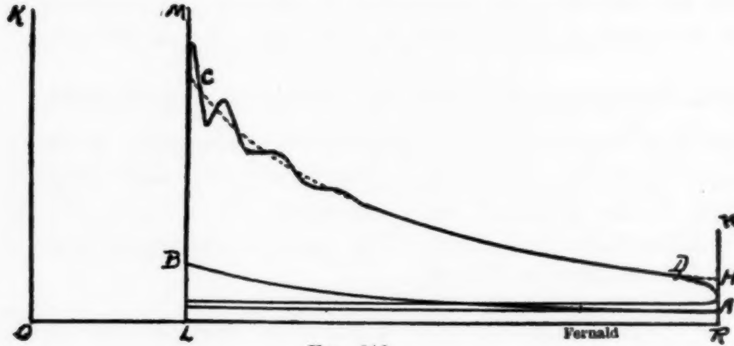

Fig. 312.

length of the diagram is determined by the lines *LM* and *RW* (Fig. 312), and is equal to *LR*.

The area in square inches divided by the length of the diagram in inches, multiplied by the scale of the spring used, will give the mean effective pressure in pounds per square inch.

Data Given.	*Solution.*
A = area diagram, sq. ins. L = length diagram, ins. S = scale of spring used. *To Find—* $M.\ E.\ P.$ = mean effective pressure.	$M.\ E.\ P. = \frac{A}{L} S$
Examples. "A" Run No. 6: A = .84 sq. ins. L = 3.04 ins. S = 240 lbs. per inch height.	$M.\ E.\ P. = \frac{.84}{3.04} 240 = 66.3$ lbs. per sq. in
"B" Run No. 6: A = .65 sq. ins. L = 2.76 ins. S = 240 lbs. per inch height.	$M.\ E.\ P. = \frac{.65}{2.76} 240 = 56.5$ lbs. per sq. in.

EXHAUST.

37. *Temperature, Degrees Fahr.*

64. The subject of exhaust temperatures has occasioned much discussion since the advent of gas engines, but, as far as the writer

is informed, very few methods have been devised for securing even an approximation to the correct temperatures, and even these devices seem too complicated or too expensive for ordinary use.

Until recently there seems to have been little or no comprehension of the real temperatures of these exhaust gases, and to-day, even when an appreciation of the high range of temperatures is had, there seems to be a feeling that some slight modification of the design of the engine will enable the inventor to save this excessive waste, and thus to secure for himself the fortune that would result from the invention of engines showing a higher efficiency. In the writer's opinion this cannot be done with engines working on the

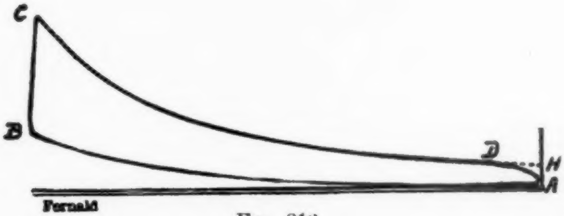

FIG. 313.

Otto or Beau de Rochas cycle, save by a reduction of the final or exhaust pressure. It can be easily shown that with high pressure of release, high exhaust temperatures must follow. Some attempts have been made to reduce this terminal pressure by compounding or other means, and while some degree of success has been attained, yet the results have not been of a nature to create any great enthusiasm, and this leads at once to the query, "Is this the best cycle to use for the most effective results?" It is not within the scope of this paper to treat this problem, but experimental results lead to renewed interest in the paper read by Mr. Charles E. Lucke at the last meeting of the Society, entitled, "The Heat-Engine Problem," in which the possibilities of the different cycles are treated in detail, leading to strong recommendations for non-explosive engines.

65. The details of apparatus for determining the temperature of the exhaust gases are given in the paper previously referred to in paragraph 29, but the method of computation will be outlined under the present heading.

Having determined the temperature of the mixture in the cylin-

der at atmospheric pressure, as recorded in item 29, the method employed for the present deduction is very simple:

Data Given.

(See Fig. 313.)

p_a = pressure at A = atmosph. pressure = 14.7 lbs.

p_h = pressure at H = value of item 35.

T_m = absolute temp. of mixture at atmosph. pres. = item 29 + 459°.

To Find—

T_h = absolute temp. of exhaust.

Solution.

The volumes at A and H being equal,

$$\frac{T_h}{T_m} = \frac{p_h}{p_a} \quad \text{or} \quad T_h = T_m \frac{p_h}{p_a}$$

$$T_h - 459° = \text{F.}°$$

Examples.

"A" Run No. 6:

$p_a = 14.7$ lbs.

$p_h = 48$ lbs.

$T_m = 106° + 459° = 565°$

$$T_h = 565 \frac{48}{14.7} = 1{,}846°$$

$$1{,}846° - 459° = 1{,}387° \text{ F.}$$

"B" Run No. 6:

$p_a = 14.7$ lbs.

$p_h = 40.5$ lbs.

$T_m = 113° + 459° = 572°$.

$$T_h = 572 \frac{40.5}{14.7} = 1{,}579°$$

$$1{,}579° - 459° = 1{,}120° \text{ F.}$$

66. Owing to the throttling of the entering gases the mixture in the cylinder is slightly below atmospheric pressure at full cylinder volume, but the amount is not large and is not worth considering when compared with the possible errors which may occur in obtaining the various pressures from the indicator card when a high-pressure spring is used. The temperature at release would, of course, be considerably higher than that given for the point H. That the exhaust temperatures cannot be as low as has been frequently supposed, even by recognized authorities, is readily shown by a very brief calculation:

For an extreme case give both the temperature of the mixture and the pressure H very low values, thus reducing the exhaust temperature to a minimum.

Suppose the temperature of the mixture to be as cool as the atmosphere on a cool day, say 60 degrees Fahr., and take the pressure at H as low as 35 pounds. The resulting exhaust temperature even under these extreme conditions, must be

$$T_h = 519 \frac{35}{14.7} = 1{,}234 \text{ degrees or } 775 \text{ degrees Fahr.}$$

38. *Maximum Velocity, Feet per Second.*

67. As in items 11, 17, 23, 31, this maximum velocity is for use in making comparative tests only, and for determining points of design.

39. *Specific Heat, C_v.*

68. Unless the specific heat of the exhaust gases can be readily obtained, the specific heat at constant volume may be taken the same as for air, namely, $C_v = .1691$.

RATIOS.

40. *Air to Gas to Neutrals.*

69. By "neutrals" is meant the products of combustion left in the cylinder of a non-scavenging engine after exhaust—an amount equal in volume to that of the clearance space.

In determining the proportions called for, the number of cubic feet of gas is taken as unity, and the temperature of the gas is taken as the basis for the computation. The quantities of air and neutrals must be reduced to corresponding amounts at this temperature.

The cubic feet of air used in ten minutes or an hour cannot be taken as a basis of comparison, without modification, owing to the misses of explosions, in which case air is taken into the cylinder without gas.

Data Given.

T_1 = absolute temperature of air = item 15 + 459°.

T_2 = absolute temperature of gas = item 21 + 459°.

T_e = absolute temp. of exhaust gases = item 14 of log + 459°.

at atmospheric pressure.

v' = cu. ft. gas per explosion at T_2 as computed in 29.

v'' = cu. ft. air per explosion at T_1 as computed in 29.

v_e = cu. ft. neutrals per explosion.
= volume of clearance = v_b.

To Find—

v_x = cu. ft. air per explosion at T_2.

v_z = cu. ft. neutrals per explosion at T_2.

$v_x : v' : v_z = ?$

Solution.

$$\frac{v_x}{v''} = \frac{T_2}{T_1} \qquad v_x = v''\frac{T_2}{T_1}$$

$$\frac{v_z}{v_e} \quad \frac{T_2}{T} \qquad v_z = v_e\frac{T_2}{T_e}$$

Taking v' as the basis, *i.e.* calling v' unity, then

$$v_x : v' : v_z = v''\frac{T_2}{T_1} : 1 : v_e\frac{T_2}{T_e}$$

Examples.

"A" Run No. 6:

$T_1 = 86° + 459° = 545°.$

$T_2 = 86° + 459° = 545°$

$T_e = 180° + 459° = 639°.$

$v' = .0196$ cu. ft.

$v'' = .1450$ cu. ft.

$v_e = .0550$ cu. ft.

$v_x = .145 \frac{545}{545} = .145$ cu. ft.

$v_z = .055 \frac{545}{639} = .0469$ cu. ft.

$v_x : v' : v_z = 7.4 : 1 : 2.4.$

"B" Run No. 6:

$T_1 = 87° + 459° = 546°.$

$T_2 = 87° + 459° = 546°.$

$T_e = 188° + 459° = 647°.$

$v' = .0163$ cu. ft.

$v'' = .0769$ cu. ft.

$v_e = .0370$ cu. ft.

$v_x = .0769 \frac{545}{545} = .0769$ cu. ft.

$v_z = .037 \frac{545}{647} = .0312$ cu. ft.

$v_x : v' : v_z = 4.7 : 1 : 1.9.$

41. *Stroke to Expansion.*

70. This ratio shows the regularity of the opening of the exhaust valve, *i.e.*, the position in the stroke of the point of release, and is equal to the ratio of the full stroke to the horizontal projection of the expansion curve taken to the release point. In the diagram shown in Fig. 314, it is the ratio of FA to FJ.

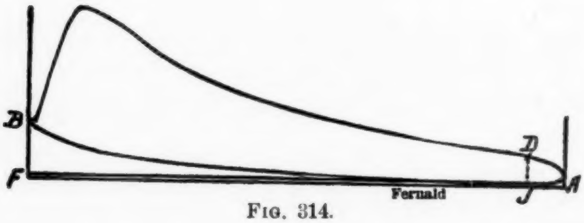

FIG. 314.

For "A" run No. 6, this ratio was 1.14, and for "B" run No. 6, 1.10.

The point of release does not seem always to correspond to the point of opening of the exhaust valve. The piston is moving rapidly and the drop in pressure is not always shown at once, especially if the exhaust valve motion is not rigid, or if the exhaust valve is of insufficient area.

42. *Volumes v_2 to v_1.*

71. In the diagram (Fig. 315), v_1 is proportional to the length OL, and represents the clearance volume of the cylinder. v_2 is

proportional to the length OR and represents the full cylinder volume—the clearance plus the stroke. The ratio $\frac{v_2}{v_1}$ is therefore equal to $\frac{OR}{OL}$. For "A" run No. 6 this ratio was 4.68 and for "B" run No. 6, it was 5.00.

43. *Maximum Pressure to Mean Effective Pressure.*

This ratio shows the relation between the pressure produced by explosion and the true working pressure, and gives an especially good idea of the possibilities of different engines in comparative tests, as well as determining the possible degree of constancy in this relation for any single engine. It is stated by some writers

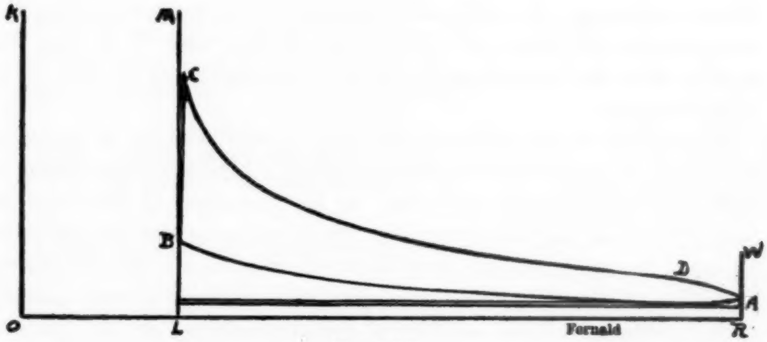

FIG. 315.

that in practice it is found advantageous to proportion the amount of metal in the moving parts to this ratio. For "A" run No. 6, the maximum pressure was 298 lbs., and the mean effective pressure as given in item 36 was 66.3 lbs., thus giving a ratio of 4.50. For "B" run No. 6, the maximum pressure was 238 lbs., and the mean effective pressure 56.5 lbs., giving the ratio of 4.21.

44. *Maximum Pressure to Compression Pressure.*

72. Not only will variations in this relation tend to show changes in the quality of the mixture, due either to fluctuations in the quality of gas used, or to differences in the proportions of air to gas; but it also gives insight into possible changes in the form

of the combustion chamber for securing the best possible flame propagation after explosion, thus insuring the most complete combustion of the mixture, or maximum measure of heat that becomes effective.

It has been claimed that conditions have been attained under which this ratio has reached a figure as high as ten, but in general it is found to be about three or three and one-half, and occasionally as high as five. Cases have been reported of six and seven, but investigation revealed the fact that the pressures were measured from the atmospheric line. "A" run No. 6 = 3.28. "B" run No. 6 = 2.62.

45. *Value of R.*

73. In order to compute the temperatures corresponding to different points in the indicated diagram, it is necessary that the temperature of some one point be known, and it is for this reason that the temperature of the exhaust gases proves of so much interest.

In engines of the ordinary size it is hardly possible to perceive by means of the indicator diagram when a high-pressure spring is used any considerable reduction in the pressure of the mixture just after entering the cylinder. In most cases the reduction in pressure is slight and has very little effect upon the temperatures, and it is sufficiently accurate to regard the pressure of the mixture at full cylinder volume as that of the atmosphere, or 14.7 pounds per square inch. If the temperature of a perfect gas varies during expansion, the product of the pressure and volume is in proportion to the absolute temperature.

"R" is the constant which enters into the mathematical statement of the above law, viz.; $PV = RT$.

Data Given.

P_0 = atmospheric pressure per sq. ft.
= 2,117 lbs. per sq. ft.

v_2 = total vol. of cylinder in cu. ft.

T_m = absolute temperature of mixture filling cylinder before compression begins.
= item 29 + 459°.

To Find—

R = a constant.

Solution.

By the above law:

$$P_0 v_2 = RT_m$$

$$R = \frac{P_0 v_2}{T_m}$$

Examples

"A" Run No. 6:

$P_0 = 2{,}117$ lbs. per sq. ft.
$v_2 = .260$ cu. ft.
$T_m = 106° + 459° = 565°.$

$$R = \frac{2{,}117 \times .260}{565} = .973$$

"B" Run No. 6:

$P_0 = 2{,}117$ lbs. per sq. ft.
$v_2 = .1844$ cu. ft.
$T_m = 113° + 459° = 572°.$

$$R = \frac{2{,}117 \times .1844}{572} = .681$$

46. *Temperature, Degrees Fahr., at Compression.*

74. Having determined "R," as in 45, the temperatures corresponding to any point in the diagram are readily determined by the general formula used in obtaining "R" after solving for T.

Data Given.

In general.
P = pressure in lbs. per sq. ft.
V = corresponding vol. in cu. ft.
R = constant determined in 45.

To Find—

T = absolute temperature corresponding to the point of the diagram selected.

Solution.

$$T = \frac{P\,V}{R}$$

$$T - 459° = F°$$

For the temperatures of compression.

Examples.

"A" Run No. 6:

P = pressure at compression per sq. ft.
$= 91 \times 144 =$ item 35×144.
$V = v_b =$ clearance vol. $= .055$ cu. ft.
$R = .973$ from 45.

$$T_b = \frac{91 \times 144 \times .055}{.973} = 741°$$

$$741° - 459° = 282° \text{ F.}$$

"B" Run No. 6.

P = pressure at compression per sq. ft.
$= 91 \times 144 =$ item 35×144.
$V = v_b =$ clearance vol. $= .037$.
$R = .681$ from 45.

$$T_b = \frac{91 \times 144 \times .037}{.681} = 711°$$

$$711° - 459° = 252° \text{ F.}$$

47. *Maximum Temperature, Degrees Fahr.*

75. Since the maximum temperature does not necessarily correspond to the maximum pressure, but depends upon the maximum value of the product of pressure and volume, it would in general be determined by the formula used in 46.

In cases where the ignition line rises vertically from the point

of maximum compression and where the expansion curve drops at once from the maximum pressure, it is apparent that the maximum temperature corresponds to the maximum pressure. Under these conditions, the volumes being equal, the absolute tempera-

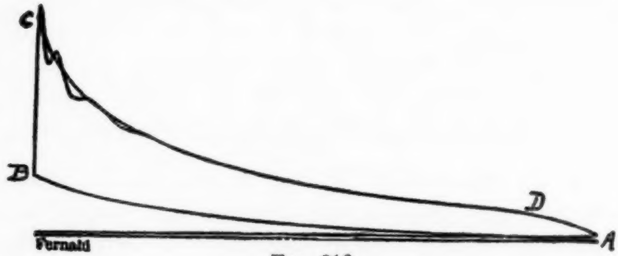

FIG. 316.

tures will be proportional to the pressures. The diagrams from the two engines considered present the different conditions very clearly in the runs selected.

Consider the diagram, Fig. 317, for run No. 6 of test " B."

Data Given.

p_c = maximum pressure, lbs. per sq. in. = item 36.

p_b = compression pressure, lbs. per sq. in. = item 35.

T_b = absolute temp. at compression = item 46 + 459°.

To Find—

T_c = absolute maximum temperature.

Example.

p_c = 298 lbs. per sq. in.

p_b = 91 lbs. per sq. in.

$T_b = 282° + 459° = 741°$.

If the same computation be made by the formula of 46, the clearance volume v_b, is necessary.

v_b = .055 cu. ft.

Solution.

$$T_c = T_b \frac{p_c}{p_b}$$

$$T_c = 741 \frac{298}{91} = 2{,}429°$$

$$2{,}429° - 459° = 1{,}970° \text{ F.}$$

By the method of 46

$$T_c = \frac{298 \times 144 \times .055}{.973} = 2{,}429°$$

$$2{,}429° - 459° = 1{,}970° \text{ F.}$$

Consider the diagram, Fig . 317, for run No. 6 of test " B."

76. In this case it is not apparent without some calculation at which point the maximum temperature will occur. Since $T = \frac{PV}{R}$ it is only necessary to determine the point for which the product

of the pressure and volume is a maximum. The most direct and simplest method seems to be by direct trial by measurement, as follows:

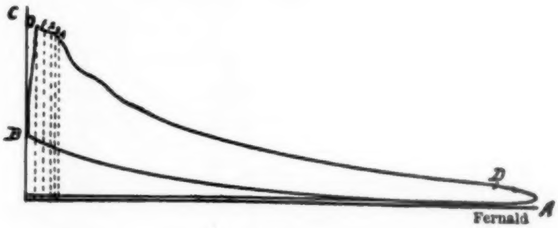

FIG. 317.

For the points 0, 1, 2, 3, 4, the volumes in cubic feet are respectively

.0395	.0417	.0438	.0453	.0460

and the pressures in pounds per square inches are

238	233	228	225	221

The products of the corresponding pressures and volumes are

9.42	9.74	10.00	10.20	10.15

showing the point marked 3 to have the highest temperature. Using the value of R deduced in 45, the temperature for the point 3 is found to be

$$T_3 = \frac{225 \times 144 \times .0453}{.681} = 2{,}159° = 1{,}700° \text{ F.}$$

ENERGIES.

48. *Brake Work in Foot Pounds.*

77. The usual method of measuring the output of an engine is by means of some form of friction brake. At times special dynamometers are used, but usually some form of the simple prony brake.

For moderate powers the form of brake shown in Fig. 318 has been found very satisfactory.

It consists of two or more cotton or hemp ropes one-half or five-eighths inch in diameter encircling the wheel and held in place by five or six blocks of wood fitting loosely over the rim of the wheel, and to which the ropes are fastened. The bottom tie-bar

of the standards is fitted with a knife edge which rests on ordinary platform scales. The upper ends of the ropes are attached to a movable block, which can be adjusted by means of the hand-wheels to produce any desired friction upon the wheel.

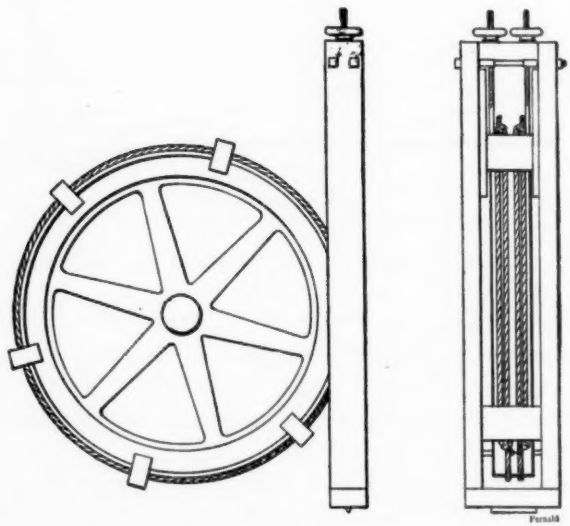

FIG. 318.

78. The downward pull of the ropes produced by this friction is transmitted through the frame of the brake to the scales.

If the wheel face be fairly wide and the diameter of the wheel large, the surface exposed to the air will allow sufficient radiation to keep the temperature of the wheel low enough to avoid the necessity of the use of water. This form of brake has been found very steady, requiring little regulation.

While the writer was at the Case School of Applied Science, such a brake was used upon the ten-foot fly-wheel of a Corliss engine from which seventy-five horse-power was readily taken, and no water was found necessary for a continuous run of three hours. Six ropes one-half inch in diameter were used, the wheel rim being fifteen inches in width. The same ropes were used for several seasons, and showed no signs of wear or burning. In many cases other forms of brake would undoubtedly prove more convenient or desirable.

The determination of the brake work in foot pounds is as follows:

Data Given.	*Solution.*
P = net pressure on scales, in lbs.	Ft lbs. per min. = $P \cdot 2\pi l \cdot$ (R. P. M.)
l = effective lever arm, in ft.	In case of the special rope brake, l = radius of wheel, or $2l = D$, then
N = No. revs. per time interval.	ft. lbs. per int. = $P\pi DN$.
To Find— Foot pounds per time interval.	
Examples.	
"A" Run No. 6: P = 70 lbs. $2l = D$ = 3.75 ft. N = 2,679 revs. for 10 mins. π = 3.14.	Ft. lbs. per int. = 70 × 3.14 × 3.75 × 2,679 = 2,210,000 ft. lbs.
"B" Run No. 6: P = 30 lbs. $2l = D$ = 3.25 ft. N = 3,012 revs. for 10 mins. π = 3.14.	Ft. lbs. per int. = 30 × 3.14 × 3.25 × 3,012 = 921,000 ft. lbs.

49. *Brake Work, Foot Pounds per Hour.*

79. This is readily deduced from the last deduction:

For "A" Run No. 6 = 2,210,000 × 6 = 13,260,000 ft. lbs.
For "B" Run No. 6 = 921,000 × 6 = 5,526,000 ft. lbs.

50. *Brake Horse-power, B. H. P.*

80. Horse-power being

$$\frac{\text{ft. lbs. per min.}}{33,000}, \text{ the B. H. P.} = \frac{\text{ft. lbs. per int. from 48}}{33,000 \times \text{int.}}.$$

$$\text{For "A" Run No. 6: B. H. P.} = \frac{2,210,000}{33,000 \times 10} = 6.7.$$

$$\text{For "B" Run No. 6: B. H. P.} = \frac{921,000}{33,000 \times 10} = 2.79.$$

51. *British Thermal Units Equivalent to B. H. P.*

81. The heat unit being taken as the consumption standard, it is necessary, in order to determine thermal efficiencies, to express

the horse-powers, or ratio of doing work, in terms of this unit. Since one thermal unit is equivalent to 778 foot pounds, to convert horse-power to thermal units proceed as follows:

Data Given.	*Solution.*
1 H. P. = 33,000. ft. lbs. per min. 1 B. T. U. = 778 ft. lbs.	B. T. U. per min. for 1 H. P. = $\frac{33,000}{778}$ = 42.4.
B. H. P. = brake horse-power of 50. int. = time interval of item 2.	
To Find. B. T. U. per int. equivalent to B. H. P.	B. T. U. per int. = 42.4 × B. H. P × int.
Examples.	
"A" Run No. 6: B. H. P. = 6.70 int. = 10 mins.	B. T. U. per int. = 42.4 × 6.70 × 10 = 2,840.
"B" Run No. 6: B. H. P. = 2.79. int. = 10 mins.	B. T. U. per int. = 42.4 × 2.79 × 10 = 1,180.

52. *Indicated Horse-power, I. H. P*

82. The indicated horse-power is determined by means of the mean effective pressure obtained from the indicator diagram. When the load is variable these diagrams should be taken at frequent intervals, and it is often advisable to allow the pencil to trace three or four diagrams on the same card and use the average mean effective pressure obtained from these. Under uniform conditions these successive tracings will show little variation. When the test is continued for many hours, so that the time intervals are long, it is well to take cards at stated periods during the regular interval. These periods should seldom exceed fifteen minutes. When the regular time interval for all readings is ten or fifteen minutes one card for each interval is sufficient, provided slight variations only are found in the different cards as taken (see remarks under Pressures for Indicator Cards, following paragraph 31 of this paper, and for the calibration of indicator springs, see section xiv. of the "Report of Committee on Standardizing a System of Testing Steam Engines."

TO DETERMINE THE INDICATED HORSE-POWER.

P = M. E. P. from diagram = item 36.
L = length of stroke in ft.
A = area piston in sq. ins.
N = No. explosions per min.

$$\text{I. H. P.} = \frac{PLAN}{33{,}000}$$

Examples.

"A" Run No. 6.
P = 66.3 lbs.
L = 1.04 ft.
A = 28.3 sq. ins.
N = 133.9.

$$\text{I.H.P.} = \frac{66.3 \times 1.04 \times 28.3 \times 133.9}{33{,}000} = 7.93$$

"B" Run No. 6:
P = 56.5 lbs.
L = .75 ft.
A = 28.3 sq. ins.
N = 93.4.

$$\text{I.H.P.} = \frac{56.5 \times .75 \times 28.3 \times 93.4}{33{,}000} = 3.40$$

53. *British Thermal Units Equivalent to I. H. P.*

83. The determination is the same as that of 51, with the exception that indicated horse-power is substitued for brake horse-power.

"A" Run No. 6: I. H. P. = 7.93 B. T. U. = 42.4 × 7.93 × 10 = 3,360
"B" Run No. 6: I. H. P. = 3.40 B. T. U. = 42.4 × 3.4 × 10 = 1,440

54. *Gas Horse-power.* 55. *B. T. U. Equivalent to Gas H. P.* = H_1.

84. In order to determine the theoretically possible power, it is necessary to know the heat equivalent of the fuel used. This heat of combustion may be determined by chemical analysis or by means of a calorimeter. The calorimeter generally recommended seems to be the Mahler, for solid fuels and oils, and Junker for gas. (See "Report of Committee on Standardizing a System of Testing Steam Engines," and "Efficiency Test of a One Hundred and Twenty-five Horse-power Gas Engine," by C. H. Robertson, paper No. 907, American Society of Mechanical Engineers.)

Since the mixtures considered are explosive mixtures and are used under such conditions, a calorimeter designed and calibrated for such conditions should be used for accurate determinations. Such a calorimeter is now in operation at Columbia. When it is inconvenient to secure either a chemical or calorimeter test, it is usually possible to learn through the company supplying the fuel its approximate heat equivalent.

The number of heat units is equal to the heat equivalent of one pound of coal or oil, or one cubic foot of gas, multiplied by the quantity of fuel in corresponding units.

Data Given.	*Solution.*
H_f = heat of combustion of fuel determined by analysis or calorimeter.	
F = lbs. of coal or oil, or cu. ft. of standard gas per interval.	
To Find—	
H_1 = heat equivalent to G. H. P.	
$Gas\ H.\ P. = \frac{H_1 \times 778}{33{,}000 \times \text{int.}}$	$H_1 = H_f \times F$
Examples	
"A" Run No. 6	
H_f = 650 B. T. U. per cu. ft. gas at standard temp. 60° F.	$H_1 = 650 \times 25.2 = 16{,}400$ B. T. U.
F = 25.2 cu. ft. gas for 10 mins. = item 25 ÷ 6.	$Gas\ H.\ P. = \frac{16{,}400 \times 778}{33{,}000 \times 10} = 38.6.$
int. = 10 mins. = item 2.	
"B" Run No. 6:	
H_f = 650 B. T. U. per cu. ft. gas at standard temp. 60° F.	$H_1 = 650 \times 14.6 = 9{,}500$ B. T. U.
F = 14.6 cu. ft. gas for 10 mins. = item 25 ÷ 10.	$Gas\ H.\ P. = \frac{9{,}500 \times 778}{33{,}000 \times 10} = 22.4.$
int. = 10 mins. = item 2.	

56. *Heat Supplied, B. T. U., from Indicator Card* = H_1'.

85. There is always a wide discrepancy between the supply of heat shown by the indicator—by the pressure rise line BC of the diagrams—and that shown by the calorimeter or chemical test of the fuel.

The great difference in the values of these two quantities is readily seen by a glance at items 66 and 67, which show the efficiencies based on these different values.

The computation for the heat supplied, as shown by the indicator diagram, involves not only the temperature of compression and the corresponding temperature from the expansion curve, but strictly the specific heat of the gases before and after explosion, and during the process of explosion—a value which is indeterminate—and the total weight of these gases. This tends to seriously complicate the problem, but the specific heat will be assumed the same before and after explosion and can in both cases be regarded, without serious error, as the value given for air.

Data Given.	*Solution.*
T_m = absolute temperature of mixture in cylinder before compression = item 29 + 459°.	
T_{ag} = absolute temp. of entering air and gas as computed in paragraph 29.	
v_{ag} = vol. of entering air and gas per explosion at T_{ag} as computed in Part I. of 29.	
v_b = clearance vol. of cylinder.	
w_5 = wgt. per cu. ft. of mixture at T_m as computed in 30.	$v_t = v_{ag}\dfrac{T_m}{T_{ag}}$
C_v = specific heat at constant vol. = .1691.	$v_s = v_t + v_b$
T_c = absolute temp. of point C of diagram.	$w_m = v_s \times w_5$
T_b = absolute temp. of compression = item 46 + 459°.	$H_1' = C_v(T_c - T_b)\, w_m \times$ *Exps.*
Exps = total explosions per time interval.	
To Find—	
v_t = vol. entering air and gas at T_m.	
v = total vol. per explosion of mixture before compressing.	
w_m = total wgt. of mixture in cylinder.	
H_1' = heat supplied in B. T. U. per time interval.	
Examples.	
"A" Run No. 6:	
$T_m = 106° + 459° = 565°$.	$v_t = .1646\dfrac{565}{545} = .1710$ cu. ft.
$T_{ag} = 545°$.	
$v_{ag} = .1646$ cu. ft.	$v_s = .171 + .055 = .226$ cu. ft.
$v_b = .055$ cu. ft.	$w_m = .226 \times .0701 = .158$ lb.
$w_5 = .0701$ lb.	$H_1 = .1691\ (2{,}429 - 741)\ .158 \times 1{,}339$
$C_v = .1691$	$= 6{,}040$ B. T. U.
$T = 1{,}970° + 459° = 2{,}429°$.	
$T_b = 282° + 459° = 741°$.	
Exps. = 1,339 for 10 mins.	

86. The determination of the temperature (T_c), corresponding to the point C of the diagrams is not always as readily made as in the case just cited, as may be observed by inspecting Figs. 316 and 317. In Fig. 316, which corresponds to run No. 6, of test "A," the line BC of the diagram coincides with the line drawn through B parallel to the line of zero volumes, thus making T^c and the maximum temperature, deduced in 47, identical. When these fortunate conditions do not exist, as in Fig. 317, or run No.

6 of test "B," it is necessary to continue the expansion curve to the point C, as in the computation for H'_1 it is specified that the temperatures must be taken for constant volume points.

When any question exists regarding the true value of n for the equation of the expansion curve near the point C, the curve may be continued from points below by the eye and the value thus obtained for C checked with that found by the equation. In the present instance the pressure at C was found to be about 282 pounds.

Having determined the pressure at C as just indicated, the temperature may be readily computed by the formula $T = \frac{PV}{R}$ or more easily by direct proportion, since the temperature at B is already known. By the latter method

$$T_c = T_b \frac{p_c}{p_b} \text{ or } T_c = 711 \frac{282}{91} = 2{,}203^\circ \text{ or } 1{,}744^\circ \text{ F.}$$

This result is quickly checked by the other method, or

$$T_c = \frac{288 \times 144 \times .037}{.681} = 2{,}203^\circ.$$

Continuing with the original problem,

"B" Run No. 6:

$T_m = 113^\circ + 459^\circ = 572^\circ$
$T_{ag} = 546^\circ$
$v_{ag} = .0932$ cu. ft.
$v_b = .037$ cu. ft.
$w_5 = .0692$ lb.
$C_v = .1691$
$T_c = 2{,}203^\circ$
$T_b = 711^\circ$
$Exps. = 934$ per 10 min.

$v_t = .0932 \frac{572}{546} = .0976$ cu. ft.
$v_s = .0976 + .037 = .1346$ cu. ft.
$w_m = .1346 \times .0692 = .0093$ lb.
$H_1' = .1691\ (2{,}203 - 711)\ .0093 \times 934$
$= 2{,}190$ B. T. U.

87. In the solution of Heat Extracted, B. T. U. from indicator cards, $= H_2'$, item 58, the same values of C_v, w_m, and $Exps.$ enter the calculations. It is, therefore, well in working the above to take the product C_v, w_m, $. Exps.$ for each run and tabulate the results under a heading "K" for further use.

Thus for "A" No. 6, $K = .1691 \times .158 \times .1339 = 3.58$,
and for "B" No. 6, $K = .1691 \times .0093 \times 934 = 1.47$.

57. *Heat Extracted, B. T. U., by Observation* $= H_2$.

88. This value is determined by an analysis of the exhaust gases from which the heat equivalent of a cubic foot of these gases is determined.

Data Given.

T_e = absolute temp. exhaust at atmospheric pressure.
= item 14 of log + 459°.
T_m = absolute temp. of entering mixture = item 29 + 459°.
C_p = specific heat at constant pressure.
T_{ag} = absolute temp. of combined air and gas as found in 29.
v_{ag} = combined vol. of air and gas per explosion at T_{ag}.
T_k = absolute temp. of exhaust as analyzed.
h = B. T. U. per cu. ft. exhaust gases at T_k as found by analysis.
Exps. = explosions per time interval.
w_s = weight per cu. ft. by analysis.

To Find—

v_k = vol. in cu. ft. at T_k per explosion.
w_k = total weight per explosion.
H_3 = total heat exhausted, B. T. U., per time interval.

Solution.

$$v_k = v_{ag} \frac{T_k}{T_{ag}}$$

$$w_k = w_6 \times v_k$$

$$H_3 = C_p (T_e - T_m)\, w_k \times Exps. + h \times v_k \times Exps.$$

58. *Heat Extracted, B. T. U., from Indicator Card* $= H_2'$.

89. This is the heat thrown off in the exhaust as derived from the pressures shown by the indicator card.

Data Given.

T_h = absolute temp. of exhaust = item 37 + 459°.
T_m = absolute temp. of mixture at atmospheric pressure = item 29 + 459°.
$K = C_v \times w_m \times Exps.$ as found in 57.

To Find—

H_3' = heat rejected, B.T.U., per time interval.

Solution.

$$H_3' = K(T_h - T_m)$$

Examples.

"A" Run No. 6:

$T_h = 1,387° + 459° = 1,846°$.

$T_m = 106° + 459° = 565°$.

$K = 3.58$ from 57.

$H_2' = 3.58\ (1,846\text{-}565) = 4,580$ B. T. U.

"B" Run No. 6:

$T_h = 1,120° + 459° = 1,579°$.

$T_m = 113° + 459° = 572°$.

$K = 1.47$ from 57.

$H_2' = 1.47\ (1,579\text{-}572) = 1,480$ B. T. U.

Both in this solution, and in that of 57, since the difference of temperatures is involved, the common factor may be omitted if desired, and the temperatures taken directly from the report blank in Fahrenheit degrees. Thus for "A" run No. 6.

$t_h = 1,120°$.

$t_m = 113°$. $\quad H_2'\ 1.47\ (1,120\text{–}113) = 1,480$ B.T.U.

$K = 1.47$.

59. *Indicated Horse-power Minus Brake Horse-power.*

90. The difference between these powers is frequently called the friction horse-power. It is not alone the power required of the engine to drive its own mechanism, but includes the error due to inability to take indicator cards every explosion. This is especially important with two cycle engines with throttling governors.

The calculation consists simply in subtracting the value of item 50 from item 52.

For "A" run No. 6 this is $7.93 - 6.70 = 1.23$,
and for "B" run No. 6, $3.40 - 2.79 = 0.61$.

60. *Throttling of the Entering Mixture, Cu. Ft. per Explosion.*

91. It is found, as might be expected, that the final volume of the mixture in the cylinder before compression is not equal to the full cylinder volume if the mixture is taken at atmospheric pressure. This is caused in part by the brief time allowed for entering, and in part by valve friction. In large engines this throttling may become serious, and all valves should be positively moved and not moved by suction.

Owing to many conditions which affect this result, the calculation of the amount is approximate only, but gives an idea of results of this throttling action.

In computing 56 the value v_s obtained is equal to the total volume for explosion of mixture at atmospheric pressure before compression, expressed in cubic feet. The total volume of the cylinder minus this value gives the effect of throttling.

"A" Run No. 6.

$$\begin{aligned} \text{Total cylinder vol.} &= .260 \text{ cu. ft.} \\ \text{From 57, } v_s &= .226 \text{ cu. ft.} \\ \text{Throttling} &= .034 \text{ cu. ft.} \end{aligned}$$

"B" Run No. 6.

$$\begin{aligned} \text{Total cylinder vol.} &= .1844 \text{ cu. ft.} \\ \text{From 57, } v_s &= .1346 \text{ cu. ft.} \\ \text{Throttling} &= .0498 \text{ cu. ft.} \end{aligned}$$

61. *Percentage of Throttling.*

This is the ratio of the cubic feet throttled to the total cylinder volume in cubic feet.

$$\text{"A" Run No. 6:}\quad \frac{.034}{.260} = 13.1 \text{ per cent.}$$

$$\text{"B" Run No. 6:}\quad \frac{.0498}{.1844} = 27.0 \text{ per cent.}$$

62. *Work that would be Added if Expansion were Complete.*

92. A point of considerable interest was presented in attempting to make the computations involved in this column. The mathematical work required is given below:

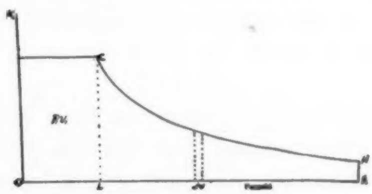

FIG. 319.

To find the area under the expansion curve proceed as follows:

$$pv^n = p_1 v_1^n$$
$$p = p_1 v_1^n v^{-n}$$

The general expression for the area is

$$A = \int_{v_1}^{v_2} p\, dv,$$

Substituting the value of p found above

$$A = p_1 v_1^n \int_{v_1}^{v_2} v^{-n} dv$$

$$A = p_1 v_1^n \frac{v_2^{1-n} - v_1^{1-n}}{1-n}$$

$$A = \frac{p_1 v_1^n}{n-1} (v_1^{1-n} - v_2^{1-n}),$$

which reduces to

$$A = \frac{p_1 v_1 - p_2 v_2}{n-1}$$

A glance at this formula reveals the fact that the value of A, which corresponds to the work done, depends upon the value of n, and in carrying out the solution any variation in n makes such serious variation in the value of A that no dependence can be placed upon the values obtained unless the values of n can be guaranteed correct. The time at command does not allow further investigation at present, but the trial solutions revealed a possible method of making more accurate determinations of the value of n than can possibly be made by the method employed in paragraph 28. The difficulty arising from slight variations in n prevented any attempt to supply the results called for in this column of the report.

EFFICIENCIES.

93. The efficiency may be expressed in many different forms, as indicated, and in general it is very essential, when referring to the efficiency of a gas engine, to designate clearly to which efficiency reference is made, in order to avoid serious misunderstanding.

The mathematical deductions are so fully indicated in the headings of the various columns that further explanation about the details seems unnecessary, and only general remarks will be made under each paragraph.

$$63. \ \textit{Mechanical} = \frac{\textit{item } 50}{\textit{item } 52}.$$

94. This efficiency is the ratio of the power which can be taken from the engine to the power shown by the indicator card. It therefore depends much upon the smooth, easy running of the engine itself.

$$\text{"A" Run No. 6} = \frac{6.70}{7.93} = .846$$

$$\text{"B" Run No. 6} = \frac{2.79}{3.40} = .822$$

64 *and* 66. *Thermal for B. H. P. and I. H. P.*

95. In these cases the efficiency is based upon the total heat put into the engine as shown by the calorimeter or chemical analysis of the fuel. Item 64 shows what percentage of the total heat in the fuel is converted into useful work and item 66 shows the percentage of the total heat converted for both useful and useless work.

"A" Run No. 6:

$$\text{For B. H. P.} = \frac{2,840}{16,400} = .173$$

$$\text{For I. H. P.} = \frac{3,360}{16,400} = .205$$

"B" Run No. 6:

$$\text{For B. H. P.} = \frac{1,180}{9,500} = .124$$

$$\text{For I. H. P.} = \frac{1,440}{9,500} = .152$$

65 *and* 67.

If the basis for computing the efficiency be that of the heat actually shown to be supplied by the indicator, then the thermal efficiency is much higher. This basis has been used in computing items 65 and 67.

"A" Run No. 6:

$$\text{For B. H. P.} = \frac{2,840}{6,040} = .471$$

$$\text{For I. H. P.} = \frac{3,360}{6,040} = .557$$

'B" Run No. 6:

$$\text{For B. H. P.} = \frac{1,180}{2,190} = .539$$

$$\text{For I. H. P.} = \frac{1,440}{2,190} = .657$$

68, 69 *and* 70.

96. In these columns are given other methods of estimating the efficiency, based as before on both the heat supplied and extracted

as determined directly from the gases, and as determined from the indicator diagram.

For item 69, $\frac{H_1' - H_2'}{H_1'}$, the efficiencies were

$$\text{"A" Run No. 6: } \frac{6{,}040 - 4{,}580}{6{,}040} = .242$$

$$\text{"B" Run No. 6: } \frac{2{,}190 - 1{,}480}{2{,}190} = .324$$

The necessity of clearly designating the efficiency selected is made very apparent by a comparison of the values given in the preceding paragraph.

STANDARD GAS PER HOUR.

97. In order for comparison to be made it is very essential that some standard be adopted for estimating the quantity of gas used. The basis of reckoning item 25, which has previously been recommended by a few writers, seems to be the proper one, and therefore standard gas is interpreted to mean gas under atmospheric pressure and at a temperature of 60 degrees Fahr.

71. *Fuel per Indicated Horse-power per Hour.*

98. This is readily obtained by dividing the values in column 25 by the corresponding values in column 52.

$$\text{"A" Run No. 6: } \frac{151}{7.93} = 19 \text{ cu. ft. per hr.}$$

$$\text{"B" Run No. 6: } \frac{87.5}{3.4} = 25.7 \text{ cu. ft. per hr.}$$

72. *Fuel and Igniter per Indicated Horse-power.*

In case of flame or hot tube ignition the gas used should be passed through a separate meter and for the data in this column the quantity of standard gas used for fuel combined with that used for the igniter will give the total standard gas per hour. This quantity, divided by the indicated horse-power, will give the desired value.

73 *and* 74. *Fuel, and Fuel and Igniter, per Brake Horse-power.*

99. The method of procedure is the same as in 71 and 72, save that the brake horse-power is now used instead of the indicated horse-power.

FUEL PER B. H. P.

$$\text{“A” Run No. 6: } \frac{151}{6.70} = 22.5 \text{ cu. ft.}$$

$$\text{“B” Run No. 6: } \frac{87.5}{2.79} = 31.4 \text{ cu. ft.}$$

75. *Cost per Indicated Horse-power per Hour, Cents.*

100. The value $1.00 per thousand cubic feet of standard gas is taken as a basis for determining the comparative cost of different engines. A similar deduction would be made for other fuels, based on an average cost of that fuel. In case the gas used for the igniter is reckoned in this cost, then when electric ignition is used the cost of maintaining the battery should also be considered, in order to make a proper comparison. For relative cost it is as well to disregard the igniter and base the computation on the quantity of fuel alone.

Since the fuel used in run No. 6 was 19 cubic feet for " A " and 25.7 cubic feet for " B," it is readily seen that the cost per indicated horse-power per hour was 1.9 cents and 2.57 cents respectively.

TOTALS AND AVERAGES.

101. In order to get a general series of values for the engine in question it is often well to average the results obtained under the same conditions. For this purpose space has been reserved on the report blank for the necessary totals and averages.

HEAT BALANCE.

102. By means of the heat balance a general idea is formed of the distribution and uses of the heat. As is apparent, the first result is the average of the results in item 53; the second of those in item 12; the third of those in item 58. To the last result is charged all the heat otherwise unaccounted for. The average of the British thermal units obtained from the gas as determined from item 55 is used as the basis in determining the percentages.

DISCUSSION.

Prof. C. H. Robertson.—I have been very much interested in the paper presented by Mr. Fernald, and have found it quite sug-

gestive in several particulars. I desire to submit the following questions and suggestions:

What are the reasons for arranging the running logs so that the different figures of any item are in horizontal lines? The writer has always kept the same in vertical lines and has found it very convenient and satisfactory, and would raise some question as to whether the horizontal arrangement is an improvement.

If I understand the meaning of the author, in paragraph 13 on "Time Intervals," to be that there is an error from too frequent observations, I should like to ask in what way this error occurs. It is implied that two or three hours is not a long time for tests, and in some cases it may be necessary to run several hours. It seems to me that, generally speaking, it is not necessary to run any such length of time, provided that the test does not involve a gas producer, or unless there is very great fluctuation in the heating value of the gas used.

In paper No. 895, *Transactions*, vol. xxii., page 620, may be seen the result of cutting up a long test into a number of short periods, making a series of tests of ten minutes' duration. The regularity and consistency of the curves shown in the paper is sufficient justification, it seems to me, for the statement that these tests of ten minutes' length were sufficient. During the last five years I have directed the course of hundreds of tests of ten and fifteen minutes' length, and the regularity and consistency of the curves plotted from the data gives satisfactory evidence that this length of time is sufficient.

It is not suggested that ten minutes is always long enough, but it is suggested that most gas-engine tests, not involving a gas producer, are longer than they need to be. This may not seem an important question at first sight, but when one is attempting to get the effect of several of the factors on the performance of a gas engine, and is carrying on an investigation that consists of 300 or 400 tests, the time factor becomes an element of considerable importance.

In paragraph 16, on the "Determination of Total Explosions," I wish to suggest that it is often desirable to have a counter for registering the number of explosions operated by the force of the exhaust. Such an apparatus is easily arranged, and we have used one for several years in our gas-engine work at Purdue University. Another counter attached to the gas-inlet valve arm serves to show the number of inlets, and the comparison of the readings of these

counters at once gives clear evidence as to whether the igniter is working properly. It may be said also that under some conditions of testing there will be charges that are missed even when the igniter is in proper working condition.

In connection with paragraph 18, concerning the ratio of revolutions to explosions, it is suggested that it may also be well to note the sequence of the explosion. In a number of hit-and-miss governors the explosions usually will come two, three, or four in succession, and then there will be a number of blank charges. This remark applies particularly to hit-and-miss governors running on the Otto cycle, and has a bearing upon the method of calculating the ratio of gas to air, because the first explosion of the series is one in which the exhaust space has been cleared of burnt gases and is usually filled with air, thus making these first explosions of a different mixture from those which follow in immediate succession.

It is thus seen that the ratio of the scavengered and non-scavengered is a factor to be noted for determining the proportion of gas to air even after they have both been measured by accurate meters.

It is suggested that a satisfactory method to determine the accuracy of indicator rigging is to get the engine up to the speed, then close the gas valve and hold the indicator pencil against the drum for several revolutions; the pencil will, of course, travel up and down the compression curve, and if the indicator rigging is accurate the up and down stroke of the pencil will coincide. Any inaccuracy as far as angular adjustment is concerned will be made apparent by a loop instead of a single line.

In paragraph 19 is to be found the statement of standard temperature to which the gas consumption is referred. This temperature is designated as 60 degrees. I should like to ask if the author has made any comparison of the extent to which 62 degrees is used, especially in American practice as compared with 60 degrees. The writer has preferred 62 degrees for various reasons, among which may be cited the fact that Professor Rowland after some consideration selected this temperature for conducting his experiments on the Specific Heat of Water. This temperature is recommended by Professor Peabody in his "Thermodynamics," and it has also been endorsed by Professor Thurston, *Transactions*, vol. xxi., page 427.

Prof. D. S. Jacobus.—I notice that a method is given for com-

puting the temperatures of the mixture of air and gas in the cylinder. Is this method any different from that recommended in the Report of the Committee on Engine Tests, and, if different, how great a discrepancy will there be in the numerical results which are obtained by the two methods?

*Prof. R. H. Fernald.**—The vertical arrangement of the figures in the logs and reports was the one used by the writer of the paper, but, owing to the expense of printing, the Publication Committee of the Society requested the change to the horizontal form.

In practice I should use the vertical arrangement.

The fluctuations of the average gas engine are such that care should be exercised to obtain a series of readings which will give good average results. If the total time of the test is too brief, the results are apt to be misleading, owing to the recording of extreme values, which may exist for a few minutes only.

For the " simple " test of a gas engine, I regard an hour as sufficient time for securing average results. In some cases one-half hour might do, but I prefer the longer period, and should feel doubtful about results when secured from runs of not over ten minutes' total duration.

For most readings frequent observations are of value, but for temperatures, especially for those of the exhaust gases when the receiver method is used, a certain period is necessary between readings to enable the conditions to become normal.

Answering Professor Jacobus' question, the two methods are essentially the same after the necessary data have been secured.

The difficult point in the determination is to find the temperature of the exhaust gases which is necessary for the solution of the problem.

In the Report of the Committee on Engine Tests no method is indicated for finding this exhaust-gas temperature, and, as the computation of the temperature of the mixture hinges upon this factor, the formula given seems of little value unless accompanied by a method of making the desired determination of the exhaust temperature.

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* **Author's closure, under the Rules.**

No. 951.*

ELECTRICITY IN COTTON MILLS.†

BY W. B. SMITH WHALEY, BOSTON.

(Member of the Society.)

1. In December, 1897, I presented (vol. xix., p. 467) a paper before this Society, entitled "Electricity in Cotton Mills." Considerable interest was manifested in this paper, and a reasonably fair discussion, bringing out its principal points, resulted. Much question was raised on the efficiency problem of the paper, and the consensus of the criticisms was a question as to whether it was economical so to install a cotton mill. The question of economy was raised by the author in the paper previously alluded to, and expressed in the following words: "The question which arises as to whether a generator directly connected to an economical type of engine to produce the power would consume the difference in the frictional horse-power, is one which can only be answered from institutions having such plants. It is the author's opinion that this difference of power would not be exceeded."

2. The question as to whether the electrical transmission was in itself economical on any type of prime mover is here raised. Following out the line indicated in the above paper, I have had the good fortune recently to install several cotton mills generating their power electrically by means of steam engines, and as nearly as possible to compare the results of this power from an economy

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* Presented at the Boston meeting (May, 1902) of the American Society of Mechanical Engineers, and forming part of Volume XXIII. of the *Transactions*.

† For further reference on the same topic, consult *Transactions* as follows:

Vol. XIX., p. 467: "Electricity in Cotton Mills." W. B. Smith Whaley.

Vol. VI., p. 461: "The Power Required to Overcome the Frictional Resistance of Engine and Shafting in Mills." John T. Henthorn.

Vol. XVIII., p. 861: "Electricity vs. Shafting in the Machine Shop." C. H. Benjamin.

Vol. XXI., p. 912: "Electrical Transmission in Factories and Mills." W. S. Aldrich.

standpoint with those already quoted, and with other data which have been previously obtained on this very important subject.

3. The two mills alluded to in the paper of 1897 were first the Richland Cotton Mills, driven in the usual way with rope transmission and belts; and second, the Granby, a mill driven electrically, purchasing its current from an outside source and measuring it on the switchboard at the mill. In the first one, the Richland, we have a case of indicator cards on the cylinder, measuring the power direct and the deductions obtained from such tests, which gave for that mill 26 per cent. for all lost energy other than that producing work; this we termed the friction loss of the mill. In the case of the Granby, the power was measured from the switchboard, and, comparing with the figures of the values deduced from the different machines, gave for the Granby mill a loss of 17 per cent. from the switchboard to the work produced; what it took to produce that power, or what it would take to produce that power before the board was reached, was an unknown quantity, and one which could only be surmised, but which is distinctly reached in the latter part of this paper.

4. The Olympia Cotton Mills, constructed since that time in Columbia, S. C., where the other two mills are located, supplied the necessary information as to the balance of the power, and these are the figures, in comparison with those previously given, which I desire to present.

The Olympia Cotton Mills is somewhat larger than the others; it derives its power from McIntosh & Seymour vertical engines, generating electricity from direct-connected generators and supplying the mill in all of its departments, which are subdivided on the same general plan as the Granby Cotton Mills. Here we have the missing link; namely, the power from the generating source to the board, the point from which the Granby power was measured. Their relative measurements would be as follows:

Richland, indicator cards to work produced.

Granby, switchboard to work produced.

Olympia, indicator cards to switchboard, to work produced.

The difference between the Richland's 26 per cent. and the Granby's 17 per cent. is 9 points; how many of these would be absorbed from the switchboard to the indicator cards is the question with which we are dealing, as well as the general friction results.

5. The Olympia Cotton Mills is peculiarly well arranged for

making these tests; the board has indicating wattmeters from the generators, and indicating wattmeters to each one of the motors in the mill; therefore, at all times the power consumed by any motor is easily distinguished and the subdivision measured more minutely than it could possibly be under less advantageous conditions. The results of the investigations up to date, shown in the following tables, will, I am sure, be interesting. Opinions expressed here are formed from observations and from the tables appended to this article, which give very fairly and fully the general results, each one will be able to form opinions of his own on this very important subject.

6. It should be borne in mind that the nature of the service—namely, the alternating current with induction motors—is quite different in its action from the direct current or similar conditions in a belt or rope-driven mill. The effect of acceleration is reduced practically to zero in this type of electric mill; there is a fixed ratio in the speed of the generators and motors which will not permit one part to accelerate in revolutions or retard over another; in electrical terms, this is caused by the fact that within the range of the torque of the machines, the step of the machines in phase with the system will not permit of any increase in speed without stopping any machines which get out of phase. The generators running in parallel are always in step and cannot change; consequently it is impossible to speed up or down one part of the plant over another due to variation of the work.

7. The motors all run at the relative speeds compared to the generator for which they were designed, and any tendency to acceleration is checked and results in a diminution of the torque or displacement angle due to the fly-wheel effect of the armatures; within this range the entire tendency to vary the speed is absorbed. They are General Electric motors, Type I., 8 poles, 150 horse-power, 600 revolutions per minute at no load, and 588 revolutions per minute at full load, running at 550 volts. A few are of less power but the same type. The accumulated energy causes an apparent reflex action of current, and the only effect which occurs is a reduction of the power absorbed by the system, which instantaneously adjusts itself between the motors and the generators, and reduces, as shown in the horse-power tables taken from the engines, the amount of power consumed in the cylinders, the speed at all times being practically constant. Under these conditions an absolutely steady speed is maintained, and the entire

tendency to acceleration or retardation is absorbed in the machines themselves, insuring an absolutely uniform application of power at all times throughout the plant.

8. In order to represent graphically the conditions which apparently exist in these plants, I show herewith Fig. 320, which illustrates the conditions existing from time to time in the system. Assuming that the circles represent 100 per cent., then the losses due to friction, by which we will designate all energy other than that producing work, are shown by the angles x and y. x is all the friction and electrical losses from the switchboard to the work produced, and y from the indicator cards to the switchboard. In the tests the following course was pursued: The horse-power absorbed in running the engine and generator at speed without any current was measured, the two engines in use being indicated simultaneously at all times in order to annihilate any difference due to one engine leading the other in phase. The value of the total power of the light engine and generator without current is maximum y, and minimum y is shown on the tables of the horse-power and electrical output of the generator. y apparently vibrates from plus to minus. (In asserting y to be minus, it is not the intention to imply that there is no friction, but the system may return, by the inertia of the shafting and machinery, energy, to the generators from the switchboard when the generators tend to slow down. This is shown on the diagram in Nos. 4 and 5 by the fact that a part or all of y is subtracted from x, thus reducing the shaded portion. The apparent loss of energy between the indicator card and the point of application of the power is shown by that part of the diagram to the left of the vertical line.) The absorption of power as previously indicated can be readily followed from the six circles illustrating the different values of y and corresponding reduction or absorption of momentum energy in the system. It is possible under conditions of extreme lightening of the load to reduce the actual impulse of power to the generator for the short period of an absorption by the entire value of x and y. This, however, has never been the case in any observations taken.

9. In the table marked March 14 and March 19, the engines were run in parallel, with no other source of power. In the cards of March 15, March 17, and March 20 the engines were run in parallel with the water power, and show a very heavy apparent lead. On the 17th there was slight lead on the engines which is indicated

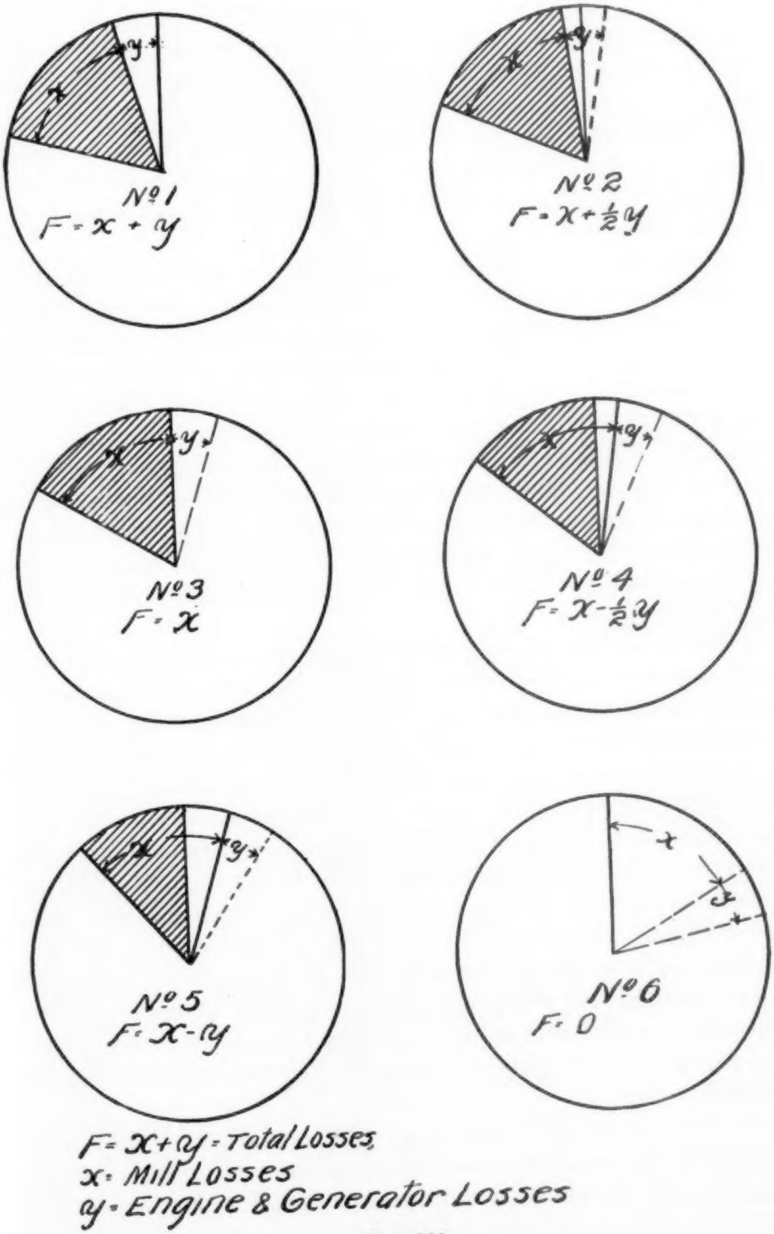
No 1
F = x + y
No 2
F = x + ½ y
No 3
F = x
No 4
F = x − ½ y
No 5
F = x − y
No 6
F = 0
F = x + y = Total Losses,
x = Mill Losses
y = Engine & Generator Losses

Fig. 320.

somewhat in the tables. The range of friction, as exhibited in values of y from these tables is from + 2.91 per cent. to — 2.78 per cent.; the average value of y seems to be very small (about .012 per cent.), or, in other words, the reflex action due to the tendency to accelerate which is checked by the step of the system, reduces the total friction by these amounts, and from the maximum in No. 1, of Fig. 320, to the possible minimum in No. 6, there is a diminution which illustrates the absorption of this internal energy in the system.

10. In Fig. 321 I endeavor to represent the conditions actually existing in the Olympia Cotton Mills at the time these tests were made. The individual tests were made, as far as possible, to cover the conditions of the motors in the mill. y on the generator circle marked A is taken at a maximum as shown in the tables of the horse-power differences, namely, + 2.91 per cent., and x is taken at its full value for mill losses. In the generator circle marked B, y becomes negative, and is taken at the lowest figure recorded in the indicated horse-power tables which are shown on set 5, March 20, and y is taken at — 2.78 per cent., showing the maximum and minimum values respectively as deduced from the tables.

11. The average of all of these 60 tests gives an average for y, or assuming that the reduction of the engine and generator losses measures the reduction of total friction, the average for all of the cards will give us for this value of y + .012 per cent. as the value of generator losses, assuming that x is not diminished. As a fact the engine and generator losses remain practically constant and the diminution in the total friction is merely a reduction of the mill friction due to the generator action in the motors in the apparent acceleration effect, pumping back current into the lines and reducing the power taken to operate the system by this amount; as it is almost impracticable to measure this reduction in the mill, the only point where we can possibly detect it is in the indicator diagrams, the results from which are given in the tables. The percentages are given in detail, the diagrams representing the different motors.

12. As may be seen in general outline, the generator is connected with the instantaneous reading wattmeter K, and the motors from the switchboard to the instantaneous reading wattmeters, i, i. From this data it appears that the friction losses in this class of work are far less than in any of the other methods of driving cotton

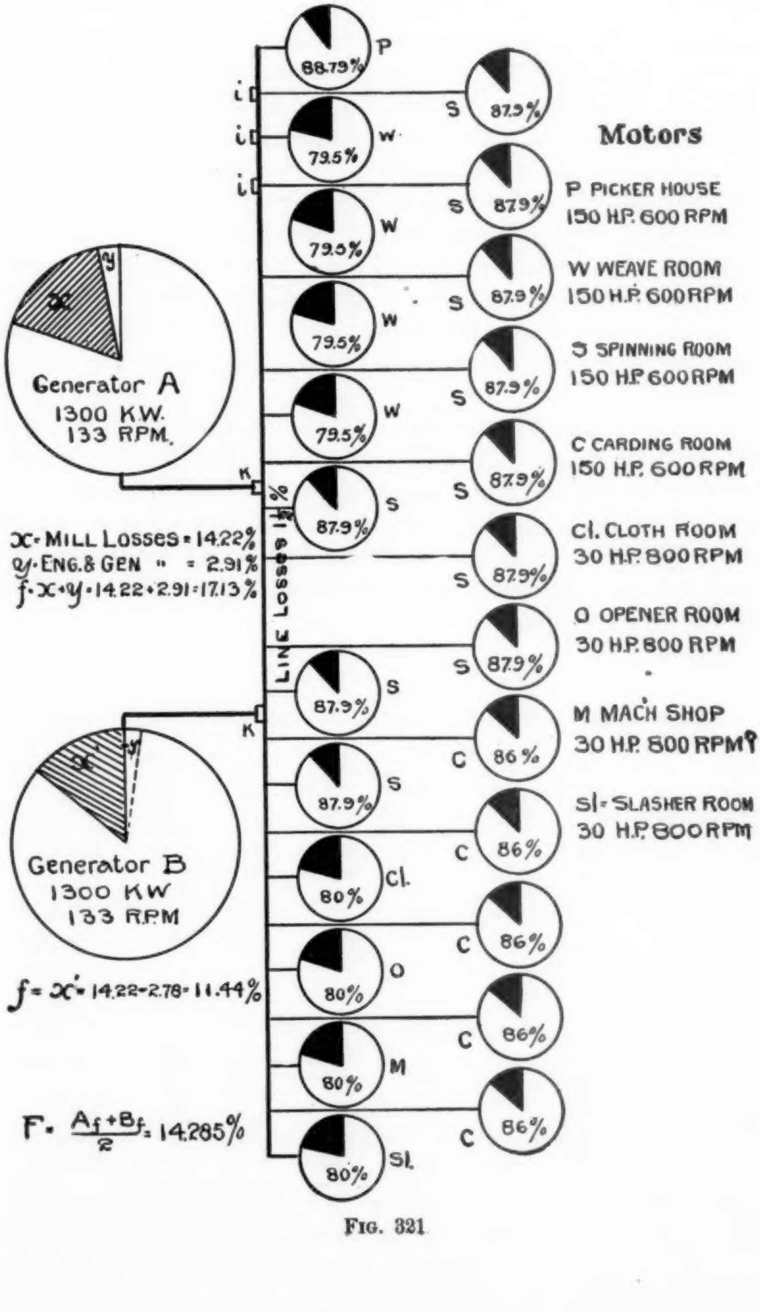
Motors
P PICKER HOUSE
150 H.P. 600 RPM
W WEAVE ROOM
150 H.P. 600 RPM
S SPINNING ROOM
150 H.P. 600 RPM
C CARDING ROOM
150 H.P. 600 RPM
Cl. CLOTH ROOM
30 H.P. 800 RPM
O OPENER ROOM
30 H.P. 800 RPM
M MACH SHOP
30 H.P. 800 RPM
Sl = SLASHER ROOM
30 H.P. 800 RPM
Generator A
1300 K.W.
133 RPM.
Generator B
1300 KW
133 RPM
x = MILL LOSSES = 14.22%
y = ENG. & GEN " = 2.91%
f = x + y = 14.22 + 2.91 = 17.13%
f = x' = 14.22 - 2.78 = 11.44%
F = (Af + Bf)/2 = 14.285%
LINE LOSSES 1½%
88.79%
87.9%
79.5%
86%
80%

FIG. 321

mills, with an apparent efficiency which is indicated by every figure obtained from the Olympia plant at present as over 82 per cent. net. With the average diminution of the total friction, the average friction on the plant apparently will not exceed 15 per cent. for all purposes. I have not endeavored to minimize this, however, in the diagrams, and a comparison of losses can now be drawn between the mills alluded to in the paper of 1897 and the present mill under discussion, as follows:

Richland, from indicator card, 26 per cent.

Granby, from the switchboard only, 17 per cent.

Olympia, from the indicator card, $14\frac{22}{100}$ per cent.

13. I append here also tables showing power taken by the machines driven by the motors and percentages of the friction obtained.

It is to be hoped that this paper will lead to more investigation on this most important subject and be criticised very freely, in order to bring out the points and views of those desiring to obtain information on these lines, that we may attempt to present to this Society, through its members, sufficient data on this very important subject to unquestionably settle the value of the different methods of driving these mills.

TABLE I.

FIRST SET. MARCH 14, 1902. UNIT NO. 3.—WITHOUT WATER POWER.

Time.	K. W.	Electric H. P.	Indicated H. P.	Dif. H. P. Pos.	Dif. H. P. Neg.	Amp.	Volts.	Apparent K. W.	P. F.
A.M. 10.12	1,020	1,367	1,387	20	...	1,150	590	1,174	.877
10.18	1,045	1,401	1,419	18	...	1,155	590	1,179	.886
10.28	1,040	1,394	1,402	8	...	1,150	590	1,174	.898
10.41	1,040	1,394	1,399	5	...	1,155	585	1,159	.897
10.52	1,020	1,367	1,353	...	14	1,150	580	1,154	.883
10.57	1,040	1,394	1,388	...	6	1,165	585	1,179	.882
Totals	6,205	8,317	8,548	51	20	6,925	3,520	7,019	5.323
Averages	1,034	1,386	1,424	...	...	1,154	586	1,169	.887

MARCH 14, 1902. UNIT NO. 1.

Time.	K. W.	Electric H. P.	Indicated H. P.	Dif. H. P. Pos.	Dif. H. P. Neg.	Amp.	Volts.	Apparent K. W.	P. F.
A.M. 10.12	995	1,334	1,334	0	0	1,095	590	1,118	.890
10.18	1,025	1,374	1,349	..	25	1,100	590	1,123	.912
10.28	1,010	1,354	1,331	..	23	1,075	590	1,107	.912
10.41	1,010	1,354	1,334	..	20	1,080	585	1,083	.932
10.52	975	1,307	1,330	23	..	1,075	580	1,080	.901
10.57	1,030	1,367	1,334	..	33	1,100	585	1,113	.916
Totals	6,135	8,090	8,012	23	101	6,525	3,820	6,626	5.463
Averages	1,022	1,346	1,335	12.5	..	1,087	636	1,104	.910

$y = \frac{21}{100}$ per cent.

SECOND SET. MARCH 15, 1902. UNIT NO. 3—WITH WATER POWER.

Time.	K. W.	Electric H. P.	Indicated H. P.	Dif. H. P. Pos.	Dif. H. P. Neg.	Amp.	Volts.	Apparent K. W.	P. F.
A.M. 9.20	880	1,179	1,280	101	..	1,050	580	1,053	.836
10.00	840	1,126	1,022	0	104	950	585	961	874
10.10	700	938	1,001	63	..	1,025	580	1,028	.682
10.20	720	965	986	21	..	980	590	989	.728
10.30	775	1,039	1,052	13	..	975	590	995	.783
10.40	700	938	942	4	..	925	595	952	.735
Totals	4,615	6,185	6,283	214	104	5,905	3,520	5,978	4.638
Averages	769	1,031	1,047	..	..	984	586	996	.773

MARCH 15, 1902. UNIT NO. 2.

Time.	K. W.	Electric H. P.	Indicated H. P.	Dif. H. P. Pos.	Dif. H. P. Neg.	Amp.	Volts.	Apparent K. W.	P. F.
A.M. 9.20	875	1,172	1,258	86	..	1,000	580	1,003	.872
10.00	840	1,126	1,123	..	3	950	585	961	.874
10.10	840	1,126	1,095	..	31	1,000	580	1,003	.837
10.20	850	1,139	1,107	..	32	950	590	961	.884
10.[illegible]	850	1,139	1,167	28	..	950	590	961	.884
10.40	820	1,099	1,093	..	6	925	595	952	.861
Totals	5,075	6,811	6,843	114	72	5,775	3,520	5,841	5.212
Averages	846	1,135	1,140.5	..	..	962	586	973	.868

$11.67 = y = \frac{23}{100}$ per cent.

THIRD SET. MARCH 17, 1902. UNIT NO. 2.—WITH WATER POWER.

Time.		K. W.	Electric H. P.	Indicated H. P.	Dif. H. P. Pos.	Dif. H. P. Neg.	Amp.	Volt.	Apparent K. W.	P. F.
A.M.	7.23	1,125	1,642	1,783	141	..	1,400	590	1,429	.857
	8.00	1,190	1,595	1,709	114	..	1,400	580	1,405	.847
	9.43	1,125	1,508	1,629	121	..	1,350	570	1,331	.845
	10.08	1,120	1,501	1,606	105	..	1,350	580	1,355	.827
	10.40	1,140	1,528	1,690	162	..	1,360	575	1,353	.842
	11.00	1,125	1,508	1,642	134	..	1,325	590	1,352	.831
Totals........		6,925	9,282	10,059	777	..	8,185	3,485	8,225	5.049
Averages.....		1,154	1,547	, 1,676	..	..	1,364	581	1,371	.841

MARCH 17, 1902. UNIT NO. 1.

Time.		K. W.	Electric H. P.	Indicated H. P.	Dif. H. P. Pos.	Dif. H. P. Neg.	Amp.	Volt.	Apparent K. W.	P. F.
A.M.	6.00	1,075	1,441	1,485	44	..	1,200	590	1,225	.873
	8.00	1,100	1,474	1,428	..	46	1,300	580	1,304	.843
	9.43	1,125	1,508	1,489	..	19	1,325	570	1,341	.839
	10.08	1,140	1,528	1,497	..	31	1,300	580	1,304	.873
	10.40	1,125	1,508	1,463	..	45	1,300	575	1,293	.869
	11.00	1,170	1,568	1,533	..	35	1,300	590	1,329	.861
Totals........		6,735	9,027	8,895	44	176	7,725	3,485	7,796	5.158
Averages......		1,122	1,504	1,482	..	..	1,287	581	1,299	.859

46 = y = 2-$\frac{31}{100}$ per cent.

FOURTH SET. MARCH 19, 1902. UNIT NO. 3.—WITHOUT WATER POWER.

Time.	K. W.	Electric H. P.	Indicated H. P.	Dif. H.P. Pos.	Dif. H.P. Neg.	Amp.	Volts.	Apparent K. W.	P. F.
A.M. 9.06	1,250	1,676	1,649	..	28	1,350	580	1,354	.923
9.40	1,275	1,709	1,621	..	88	1,350	580	1,354	.940
9.48	1,290	1,729	1,687	..	58	1,425	575	1,417	.910
9.58	1,300	1,742	1,711	..	31	1,425	590	1,454	.894
10.03	1,290	1,729	1,676	..	53	1,400	580	1,405	.918
10.10	1,275	1,709	1,646	..	63	1,400	585	1,417	.900
Totals..........	7,680	10,294	9,990	..	..	8,350	3,490	8,401	5.485
Averages......	1,280	1,715	1,665	..	..	1,391	581	1,400	.914

MARCH 19, 1902. UNIT NO. 2.

Time.	K. W.	Electric H. P.	Indicated H. P.	Dif. H.P. Pos.	Dif. H.P. Neg.	Amp.	Volts.	Apparent K. W.	P. F.
A.M. 9.06	1,060	1,421	1,405	..	16	1,225	580	1,229	.862
9.40	1,000	1,340	1,324	..	16	1,125	580	1,129	.885
9.48	1,050	1,467	1,399	..	68	1,200	575	1,194	.879
9.58	1,025	1,374	1,257	..	117	1,150	590	1,174	.873
10.03	1,050	1,467	1,505	38	..	1,200	580	1,204	.872
10.10	1,010	1,354	1,488	134	..	1,150	585	1,164	.868
Totals..........	6,195	8,423	8,378	172	217	7,050	3,490	7,094	5.239
Averages......	1,032	1,404	1,396	..	..	1,175	581	1,182	.873

$y = 1\text{-}\frac{99}{100}$ per cent.

FIFTH SET. MARCH 20, 1902. UNIT NO. 3.

Time.	K. W.	Electric H. P.	Indicated H. P.	Dif. H.P. Pos.	Dif. H.P. Neg.	Amp.	Volts.	Apparent K. W.	P. F.
A.M. 9.33	1,325	1,779	1,743	..	36	1,500	560	1,453	.903
9.41	1,375	1,843	1,767	..	76	1,510	590	1,541	.892
9.46	1,300	1,742	1,672	..	70	1,500	550	1,427	.911
9.55	1,275	1,709	1,709	..	..	1,450	550	1,400	.910
10.01	1,275	1,709	1,661	..	48	1,450	550	1,400	.910
10.10	1,275	1,709	1,633	..	76	1,410	580	1,415	.901
Totals..........	7,825	10,491	10,185	..	..	8,820	3,380	8,636	5.427
Averages......	1,304	1,748	1,697	..	..	1,470	563	1,439	.904

MARCH 20, 1902. UNIT NO. 1.

Time.	K. W.	Electric H. P.	Indicated H. P.	Dif. H.P. Pos.	Dif. H.P. Neg.	Amp.	Volts.	Apparent K. W.	P. F.
A.M. 9.33	1,020	1,367	1,294	..	73	1,200	560	1,162	.878
9.41	1,060	1,421	1,350	..	71	1,225	590	1,250	.848
9.46	1,040	1,394	1,350	..	44	1,230	550	1,170	.880
9.55	1,010	1,354	1,471	117	..	1,275	550	1,213	.832
10.01	1,080	1,448	1,412	..	36	1,310	550	1,246	.866
10.10	1,190	1,595	1,486	..	109	1,310	580	1,314	.905
Totals..........	6,400	8,579	8,363	..	..	7,550	3,380	7,355	5.209
Averages......	1,066	1,429	1,394	..	..	1,258	563	1,226	.868

$y = -\ 2\text{-}\frac{78}{100}$ per cent.

TABLE II.

Roving Motor.

Time.	34 Frames.	26 Frames.	18 Frames.	10 Frames.	2 Frames.	0 Frames.
3.20 3.38	42 K. W. 42 K. W.	35 K. W. 35 K. W.	27 K. W. 27 K. W.	18 K. W. 18 K. W.	12 K. W. 12 K. W.	10 K. W.
K. W. per Mch.	.94 K. W.	.96 K. W.	.94 K. W.	.80 K. W.	1 K. W.	14 per cent. Fric.

Spinning Motor.

Time.	38 Frames.	28 Frames.	18 Frames.	8 Frames.	0 Frames.
8.48 9.11	140 K. W. 140 K. W.	107 K. W. 108 K. W.	75 K. W. 77 K. W.	45 K. W. 43 K. W.	17 K. W.
Speed per K. W.	81.8 K. W.	82.44 K. W.	82.24 K. W.	75.71 K. W.	12.14 per cent. F.

Lapper Motor.

Time.	19 Machines.	16 Machines.	13 Machines.	10 Machines.	7 Machines.	4 Machines.	0 Machines.
2.30 2.56	70 K. W. 70 K. W.	63 K. W. 63 K. W.	56 K. W. 56 K. W.	47 K. W. 47 K. W.	42 K. W. 42 K. W.	32 K. W. 32 K. W.	9 K. W.
K. W. per Machine.	3.21 K. W.	3.37 K. W.	3.61 K. W.	3.80 K. W.	4.71 K. W.	5.75 K. W.	11.21 per cent. F.

Time, 10.15 to 11.37.

Weaving Motor.

No. Looms.	633.	591.	549.	509.	465.	423.	381.	339.	297.	255.	213.	171.	129.	87.	45.	0.
K. W.	156 152	145 145	135 137	125 129	117 123	109 115	101 105	93 98	85 92	78 85	71 77	64 70	57 63	48 53	40 45	32
Looms, per K. W.	5.10	5.23	5.33	5.45	5.47	5.49	5.52	5.55	5.60	5.54	5.46	5.34	5.16	5.43	5.6	20.5 per cent. F.

DISCUSSION.

Prof. C. H. Benjamin.—I have been asked to contribute to the discussion on this paper, presumably because of my paper some years ago on "Electricity in the Machine Shop." Unfortunately I have never had an opportunity to investigate the conditions in cotton-mills, as these are scarce in the Western Reserve.

A year or more ago I directed some tests which were made by one of my senior students in several machine shops in Cleveland, where electrical transmission is employed wholly or in part.

The results of these experiments bear directly on the question of the efficiency of this form of transmission as a substitute for shafting and belting, and this is my apology for mentioning them at this time.

I will call these shops by the numbers 1, 2, 3, and 4.

In one of these, No. 1, where direct-current motors were used, no indicator cards were taken, the power being determined by readings of the electrical instruments. In the other three cases the horse-power under different conditions was determined from indicator cards.

In shop No. 4 the generator was driven by belt from the main shaft of the shop, the system being only partial.

In shop No. 3 the average power consumed by the crane was deducted in getting the per cent. of loss.

The examples given are not at all in the same class with those mentioned by the author of the paper, representing much smaller installations and a different kind of work, but it is interesting to make the comparisons.

The percentage of friction loss is seen to be much greater, averaging about 40 per cent. of the total power, or 50 per cent. of that delivered by the generator. The power consumed by the engine and the excitation of the field is no small item, being 30 per cent. in shop No. 2, and 15 per cent. in shop No. 3.

All of these losses are relatively larger because of the fact that the generators were not loaded to anywhere near their full capacity.

These experiments point to the same conclusion as deduced from those made elsewhere, that the use of electrical transmission with the group system of driving in machine shops, entails about the

same percentage of friction loss as that resulting from ordinary shafting transmission:

Data.	Shop No. 1.	Shop No. 2.	Shop. No. 3.	Shop No. 4.
Nature of work	Heavy Mach'y	Bolts and Screws	Heavy Mach'y	Light Mach'y
Kind of current	Direct	Two phase	Two phase	Two phase
Voltage	220	240	220	240
No. of generators	One	Two	One	One
H.P. "	134	160	134	67
No. of motors	Six	Nine	Eight	Two
H.P. "	125	80	125	....
No. of machines	167	117	66	68
No. in use. Av	95	63	....	34
Horse-power				
Engine and exciter	....	25.75	13.20	....
Motors, shafting and belting	42.6	30.56	24.68	4.1
Lighting	6.13	....	....	4.7
Electric crane	....	....	35 av.	....
Machines alone	41.8	28.8	17.12	5.8
Total	90.5	85.1	90.	14.6
Per cent. loss due to motors, etc.				
of total power	....	36	45	....
of power delivered to motors	47	51.5	59	41.5

Prof. Wm. S. Aldrich.—This question of negative frictional losses is not entirely new. In electric power plants the phenomena have been earlier observed and reported to this Society. In the performance of street railway power plants, as determined on the Minneapolis and St. Paul system, Messrs. Pike and Hugo reported* a series of tests under a wide range of load variations. The direct-current railway generators were all driven by multiple-expansion engines, some belted directly, others through counter-shafting, with or without friction clutches. Such an installation afforded an excellent opportunity for observing the effects of mechanical inertia—the so-called fly-wheel effect of the transmission machinery.

Indicator cards and electric readings at the switchboard were taken every ten minutes for twenty-two hours. At the best such infrequent instantaneous readings show only the conditions existing at the time the electric observations are made. In the paper under discussion, instantaneous reading wattmeters were

* "Performance of Street Railway Power Plants." Wm. A. Pike and T. W. Hugo, *Transactions*, A. S. M. E., vol. xiv., p. 1082.

used throughout, and the several sets of observations include only six readings, at random intervals. In the cotton mill, the total load is only slightly variable. In the railway plant it is excessively rapid in its fluctuations. In each case, the same criticism is to be made. Readings are caught on the wing, so to speak. Only a very great number of them, regularly taken, can furnish results upon which engineers are to base their practice. However, by common agreement, the electrical horse-power at the switchboard deducted from the simultaneous indicated horse-power of the engine, is called the frictional loss.

In the Minneapolis test, sometimes the mechanical (engine) was in excess of the electrical (dynamo) horse-power, and just as often the reverse was the case. The mean values of all of the plus and minus differences gave the mechanical as 150 horse-power in excess of the electrical. This was taken as the frictional loss. At times, the mechanical was 400 horse-power in excess of the electrical. Then, again, the electrical would be 300 horse-power in excess of the mechanical. Had fewer readings been taken the latter condition might have been conceived as a feature of such a generating plant, though it was of the direct-current type.

Messrs. Pike and Hugo showed that when the electric railway system was lightly loaded, the difference between the mechanical powers was often minus. Therefore, the dynamo was delivering more power than the engine received from the steam. Frequently, all the losses, included in the average frictional 150 horse-power, would be completely nullified; while, from some source, the dynamo received energy to supply the traction line with current. This is just a little better performance than that approached in the Olympia Mills, where, in the paper under discussion, it is attributed to the absorption of the internal momentum energy reducing the actual impulse of the power to the generator by the entire value of the total losses, x and y. "In other words, the reflex action due to the tendency to accelerate which is checked by the step of the system, reduces the total friction by these amounts." That is exactly what it does. But for how long a time does it keep doing this? Is the total friction thus permanently reduced?

Now, it is inconceivable that any 1,300 kilowatt generating unit, can have, permanently, the friction loss, the loss from the indicated horse-power input to the dynamo output, reduced to so low a value as 2.910 per cent., which is given in this paper, for the

generator A. The generator B is taken with permanent frictional loss of minus 2.78 per cent.; in other words, this generating unit, while supplying power to the system is still somewhat of a drag on the service, due to reflex action and pumping back of line current from the induction motor service. Such external aid to the generating unit B, by whatever route it may have travelled, could only have come originally from the generator A. Notwithstanding that the average of 60 tests has been taken under as many different conditions, we cannot but think that recording wattmeters with one-minute indicator cards, for a number of days, would have shown quite different results.

Assume average, conservative values for any direct-current service of this type: mechanical efficiency of engine, 92 per cent.; commercial efficiency of dynamo, 93 per cent.; transmission line loss (as in the paper), 1½ per cent.; electric motor efficiency, 90 per cent. Perhaps this can be increased a little. Perhaps it can be brought up to 80 per cent., which, it must be remembered, is now reckoned from the indicated horse-power input to motor output. How can the alternating current still further enhance this high value and bring it up to 82 per cent., as noted in the paper? or, since, "with the average diminution of the total friction, the average friction on the plant will not exceed 15 per cent. for all purposes," we may expect the alternating current to have an aggregate efficiency from engine indicated horse-power input to motor output, of 85 per cent.

The effect of mechanical inertia, or of the fly-wheel action of the transmission and other machinery in all generating plants, is only too well known. Messrs. Pike and Hugo, in discussing their tests, attributed the plus and minus differences or losses, to bad engine regulation. We believed and then stated that it was due almost entirely to the fly-wheel action of the plant machinery. We investigated our earlier tests, of 1891, and found that similar results could be explained in like manner, in the case of an electric railway plant driven by turbines, at Reading, Pa., as reported to this Society.* Here were two vertical 250 horse-power turbines, geared to a horizontal jack shaft; this was belted back to the countershaft, and thence belted to the direct-current generator. The north turbine was controlled by an electric-contact governor. The south turbine was operated at a constant gate opening, fixed

* "Power Losses in the Transmission of Machinery of Central Stations." Wm. S. Aldrich, *Transactions*, A. S. M. E., vol. xv., page 705.

by the operating engineer according to his judgment and experience in handling this plant for the usual or normal loads. These conditions were ideal to observe two things:

First.—The plus and minus values of the so-called frictional losses, from turbine shaft to dynamo output. At times the power delivered by the turbines and generators would be equal. At other times the differences reached as high as 100 horse-power in excess of that lost in the transmission machinery and generators.

Second.—The so-called pumping or interchange of power, between prime movers, so connected that one is the controller of the system. The south turbine, under its fixed gate, was sometimes prime mover, doing its share of the work; at other times, it acted as a decided brake on the system, absorbing power, similar to generating unit *B*, of the paper under discussion.

These two features, noted in the paper, are evidently not the peculiarity of any one system. They are seen in generating plants driven by steam engines or waterwheels; in direct as well as in alternating systems. How much is due to bad regulation of the prime mover; how much to fly-wheel effect, and in the alternating-current system, how much to the action of the induction motor as a generator, when from any cause it is allowed to run at a speed above that at which it is synchronized with the generator? Of course, the induction motor never attains this ideal synchronous speed in mill practice; for beyond it conditions such as shown in diagram No. 6, Fig. 320, would become realizable. Even with no load at all there is a certain slipping of the speed of the motor behind its ideal synchronous speed. The motors noted in the paper drop 12 revolutions from no load to full load. Now, all of this slip must be made up, and the motor speeded above that of synchronism, before it will act as a generator. This it does in electric elevator service, going down, and so may there attain the conditions of relieving the generating unit of almost all of its frictional load, for a short while realizing the conditions of diagram No. 6, referred to. It may even do more than this in elevator service, and throw current on to the buss bars for the next elevator to use in going up. But the transmission machinery of any mill may approach these conditions for an instant, giving up its stored mechanical energy to drive the induction motor at a speed above that fixed by its synchronism with the prime generator, when current will be turned back and pumped into the line. But the aggregate effect of these times of reflex action can only

be determined by an integrating wattmeter. And we hope, therefore, with the author of this very interesting paper, that it will lead to more investigation on this important subject.

Mr. F. W. Dean.—I have read this paper with interest, but perhaps not in as thorough a manner as is necessary to a full understanding of it. The conclusion drawn in paragraph 12 is of such a nature that it can hardly remain unchallenged. Laying aside the question of losses in the Richland Mills, that of the Granby Mills seems quite probable. This is a loss from the switchboard to the textile machinery; that is to say, all of the electrical, belting, and shafting losses. It would naturally be supposed that in the case of the Olympia Mills the above losses and the friction of the engine and generator, and transmission losses to the switchboard, would be greater than 17 per cent., inasmuch as in electrically driven mills the total loss is very much more than that stated for the Granby Mills.

In a belt-driven mill where the connections are fairly direct, good practice indicates that the total friction up to the textile machines is about 20 per cent. It is all but startling to see that in the Olympia Mills the total losses are less than the partial losses at Granby, and this cannot stand without being seriously challenged.

As I understand the explanation of Fig. 321, it was found in certain tests that the engine friction when the generator was not developing current amounted to 2.91 per cent., and that in another case the generator friction was negative 2.78 per cent. This, of course, is a very peculiar thing. I had the curiosity to ascertain the indicated horse-power of two engines which we have installed for the American Woolen Company at the Assabet Mills, Maynard, Mass., both of which are direct-connected to General Electric generators. The engines were built by McIntosh, Seymour & Co., the larger having cylinders 32 inches and 64 inches diameter by 48-inch stroke and making 120 revolutions per minute, and the smaller having cylinders 20 inches and 40 inches diameter by 36-inch stroke and making 133 revolutions per minute. The larger engine is direct-connected to a 2,000-kilowatt generator, and the smaller to a 500-kilowatt generator. These engines were operated on Saturday afternoon, when driving merely themselves and the generators, and the friction horse-power of the larger was about 172 horse-power and that of the smaller about 64 horse-power. I have called the proper rated horse-power for these engines re-

spectively, 2,400 horse-power and 800 horse-power. This makes the friction indicated horse-power of the larger engine 7.15 per cent. and of the smaller 7.97 per cent. The indicator diagrams were fairly uniform, and there is no reason to suppose that there was any material error in the results. They are about what good practice at the present time indicates as probable, and are very much larger than any engine and generator frictions given by Mr. Whaley, and indicate that his are too small. I have never heard of any engine friction as low as he reports, and can hardly think that it is likely to be obtained.

Mr. Jesse M. Smith.—Mr. Dean, in describing the plant at the cotton mill did not, as I understand, state whether the generators were alternating or direct current. It is well known that when two alternating-current generators are run in parallel, that is when the two machines are attempting to furnish current to run the same motors, unless they run at absolute synchronism, one may be run as a motor and the other as a generator. So that it does not seem to me at all strange that in this paper by Mr. Whaley we see that the friction of the engine and generator taken together is sometimes positive and sometimes negative. As I understand, Mr. Whaley does not state that the friction of the engine is ever negative, but that the friction of the combination of each engine with its generator is negative at some times, and positive at other times; but if the friction of both combinations were taken at the same instant it would be found that their sum would be positive.

Mr. Geo. L. Fowler.—This paper on electricity in cotton mills is limited of course, in its discussion to the application of electricity to that class of mill; but the general subject is one of the greatest importance and the greatest interest to every engineer who has anything whatever to do with the development and transmission of power. The mere question as to whether it is more economical, as far as the power transmission is concerned, to deliver power direct from the engine to shafting and carry it to the machinery in that way, or use electricity as the means, is of importance, but it is of minor importance in comparison with other considerations which come in and give tremendous advantage to electrical transmission of power in shops. The cotton mill, of course, is unique in that usually, it has some power plant from which all of the machines derive their power, and the small machine shop, which was cited in the first discussion, also comes

under the same category. There is usually one engine and a line of shafting, and it is very probable that to interpose a motor or a dynamo and then group or use individual motors for the various machines, might result in failure to show any economy in the use of electricity. But in large plants, like railroad shops, where there is a great diversity of work being performed, the distances between buildings are great and power must be taken to some distance, that is where electricity comes in and does, as they say, its fine work. It is not an uncommon thing at all to see in a large railroad shop, all the way from five to ten entirely distinct steam plants, each one of them having its own attendant, and each one of them doing its work with more or less economy. Then frequently engines are placed at long distances from a central plant in order to save the expense of an attendant. You find engines standing all the way from 400 to 800 or 900 feet from the boiler at times, and the drop of pressure between the boiler and the engine, is of course very great. Railroad managers are coming to appreciate the fact that there is a tremendous economy to be secured in the matter of attendance and coal consumption by means of electrical apparatus, and all of the modern shops that are built are being so equipped. The most recent one which I have seen is on the Norfolk and Western Road at Roanoke, Virginia. There they have recently discarded, I think, eight of their independent steam plants, and put in one of about 600 horse-power with complete electric installation, and they are driving their machine shop with group motors varying from 7½ to 35 horse-power. There is another point in regard to this class of work where electricity has a tremendous advantage, even though it may not save anything in the actual transmission of power, and that is in giving more room overhead for cranes and other means of handling material. Take an ordinary machine shop where the ceilings are simply covered with counter-shafting and belting running in every direction, it is almost impossible to put in even a jib crane or an overhead pneumatic hoist, to say nothing of getting in a travelling crane which will do the work efficiently. But with the group system of driving, it is a very simple matter to arrange the shafting and the grouping of the motors in such a way that cranes are easily put in to improve the general shop efficiency. So that, in spite of the fact that electricity may not show in careful tests made in the engine-room, that there is the slightest saving over the use of shafting, there are

so many other incidental savings which come in, that it is probable that any saving which electricity might possibly show under the most favorable circumstances would sink into utter insignificance in comparison with the other savings which come in through the lowering of the cost of labor and attendance, and the increase in convenience of doing the work. This is especially true where power is needed only at infrequent intervals. Take a large railroad shop for example where there is a turn table which is used perhaps for two or three hours in the day constantly, and then may for as many hours lies perfectly idle. With a steam plant to do that work you have to have an attendant, and the steam must be up and maintained all the time. With the electric motor, the attendant may be busy about the round-house on other things, and simply goes to the table and does his work there when it is required to move an engine. That is merely one case of hundreds which occur around shops of that kind where electric driving is valuable and indicates the saving of labor and time which cannot be estimated by any kind of a computation in making a test of the comparative value of transmission of power by electricity and direct shafting.

Mr. H. H. Suplee.—Mr. Fowler has spoken of the indirect advantages of electric driving; in a discussion of this subject before the Franklin Institute in Philadelphia, our member Mr. Vauclain, stated that he estimated the saving in floor space at the Baldwin Locomotive Works, as about 40 per cent., due simply to the better arrangement of machinery. The tools could be placed where they were wanted instead of with reference to shafting, gaining the equivalent of 40 per cent. in floor space.

*Mr. Whaley.**—In reply to Mr. Dean's question as to the apparently small friction of the engine, I stated in the paper that I did not claim the apparent loss between the engine and board to be the friction of the engine. As a matter of fact, the engine, at full speed, with no load and without any current on the generator took 96 horse-power, as shown by eight cards; the full power of the engine is 2,000 horse-power. If we take this figure as the full load, that would give us 4.8 per cent. friction, and as soon as we put the current on the generator and add the load electrically by means of motors throughout the mill, we at once distribute the friction of the generator and the engine into the wires. Now, I do not claim that the friction of the engine is really diminished,

* Author's closure, under the Rules.

although I believe it is to a slight extent; I believe that the increasing of the load on the generator has a tendency to decrease rather than to increase the friction, opposite to the case of putting a load on an engine with belt or rope drive, where the pull or drag of the shaft against the bearings becomes greater as the load is increased; we accept that as a fact which has appeared from the outset, or from the time my attention was called to the apparently small engine friction last fall.

I paid special attention to the losses between the board and the indicator and, taking the cards and figuring at random, I found that it showed 3.7 per cent., three per cent., two and a fraction per cent., minus one per cent., etc., and I had also a whole lot of negative cards which gave me the impression that something was wrong and that somebody had made a mistake, so I quoted only the 3.7 per cent. as being the most probable of the figures. We got the General Electric Co. to test the wattmeters; they were checked out all right. We checked the indicators and then again took readings, with the same results. I then sent a young man, a graduate of Cornell University and a capable fellow, now in my employ, to take the indicator cards but without disclosing my reasons; he was instructed to ascertain the friction load. Two days after that, when I asked him what results he had obtained, he blushed and said that he thought he could take indicator cards, but he had a lot of them which he was sure were wrong; he had found those negative values. I then had the series of tests made, as given in this paper, with view of seeing just what really did exist, and with the results as given.

Referring to the diagrams which have been alluded to in one of the discussions—Fig. 320—I think there is a misunderstanding. I did not intend to say that, simultaneously, one engine was running positive and the other negative; I simply show in one diagram the maximum value and in the other the minimum value in order to strike the average, and it was not intended to appear as though one generator were running negative while the other was running positive. The indicator cards of those engines are taken in pairs; that is, the two engines are indicated simultaneously. It took five men to take those readings—a man on each cylinder and a man at the board reading the wattmeter, and they would take them as close as it was possible to do.

No. 952.*

TESTS OF STEAM PIPE COVERINGS.†

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I.—OBJECT OF THE TRIALS.

1. THE object of these trials which were made during October and November, 1901, was primarily to determine the commercial value of some of the leading coverings in the New York market for use in the modern power houses carrying high pressure steam, such, for example, as the Manhattan Railway Company's plant where the tests were made; and, incidentally, such other information bearing on the general subject as could be readily obtained. The tests on pipe coverings which have been made heretofore have been largely of a laboratory character; that is, they have been of somewhat short duration. They have been made, as a rule, on short sections of pipe, and generally on coverings which have been furnished by the manufacturers with the full knowledge of the purpose for which they were to be used. Without intending to pass criticism on this class of work, which so far as it goes is no doubt of excellent character, it is manifestly better, if the object in view is a commercial one, to make tests of such length and character

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† For further references on the same topic, see *Transactions* as follows :

Vol. xiv., p 827: "Pipe Covering Tests." G. M. Brill.

Vol. v., p. 73 : "Non-Conducting Coverings for Steam Pipes." J. M. Ordway.

Vol. v., p. 212 : "Non-Conducting Coverings for Steam Pipes." Second Paper. J. M. Ordway.

Vol. vi., p. 168: "Non-Conducting Coverings for Steam Pipes." Conclusion. J. M. Ordway.

Vol. ii., p. 34 : "Non-Conductors of Heat, Experiments On." C. E. Emery.

Vol. iii., p. 228 : "Note on Mineral Wool as Non-Conducting Covering." F. R. Hutton.

Vol. xix., p. 729 : "The Protection of Steam Heated Surfaces." C. L. Norton.

that they will apply to the conditions of practice, and this can only be obtained by extending the scope of the work and the duration of the tests far beyond that of the ordinary laboratory. It is hardly practicable to make a scientific test of such scope as to fully conform to the conditions of practice, for this means a test of interminable length; but it is possible to make a test on such reasonably broad lines as shall satisfy any intelligent demands, and it is believed that this has been done in the tests under consideration. Many of the coverings have been tested day after day for a continuous run of over a month, each day's run being from eight to nine hours, which is certainly a sufficient time to determine satisfactorily the efficiency of the covering during a reasonably long period of service.

2. That the coverings might represent those which are ordinarily sold and used, and not special materials prepared to order for the purposes of a test, they were ordered and purchased through a well-known house dealing in steam fitter's supplies without giving the manufacturers information as to the use to be made of the materials, or of the locality where they were to be applied. The coverings were then put on by men familiar with the work, who had plenty of time at their disposal, and who had no incentive to do other than good work without favoritism.

II.—CHARACTER AND SCOPE OF THE TESTS.

3. In view of the leading objects sought, it was decided that the tests should be made under the working conditions of the coverings; that is, that they should be "condensation" tests. No other determination of the non-conducting properties of the materials than the measurement of the amount of condensation which the coverings prevented, seemed applicable to the case. The "condensation" test furnishes a method which is entirely satisfactory, not only in its practical aspects, but in its scientific bearings. The heat radiated from a steam pipe causes a portion of the enclosed steam to be condensed, and the quantity of heat radiated is exactly proportional to the weight of steam condensed, this being a well established scientific fact. It is a matter of extreme simplicity to ascertain the quantity of steam which is condensed, for it is merely a question of weighing the resulting water on ordinary weighing scales. The quantity of radiated heat which the condensation represents is determined with equal facility by

reference to the well established tables of the properties of steam. It seems quite unnecessary, therefore, to consider any other method of testing radiation from steam pipes, when the condensation method is so readily and accurately used, and when its results are determined with such reliability as to leave nothing further to be desired. A matter, of the first importance, moreover, is that this method determines the exact thing for which non-conducting material is applied to steam pipes, which is, the quantity of condensation prevented, and the saving of fuel which covering the pipes secures.

4. "Condensation" tests require, first, that the steam supplied to the pipes which are subjected to test shall be at the outset free from condensation; in other words, dry steam. They require, second, that all the water condensed shall flow by the force of gravity to some low point from which it can be readily and completely drawn off for measurement. They require, third, that the surfaces of the pipe within shall be continuously supplied with steam, and that no air held in suspension by the steam shall collect at any point and prevent its contact with the surface. They require, fourth, that the water of condensation drawn off from the apparatus, which under the effect of the pressure of the steam in the pipe is at a temperature much above 212 degrees, shall be cooled on its escape to the weighing receptacle, so as to prevent loss of water by evaporation. The apparatus used on these tests was so arranged as to accomplish all the objects noted, as will appear in the description of the apparatus.

5. The tests were planned with a view to determining the efficiency of two classes of coverings, one designed for the extremely high pressures common in the modern power plant, viz., 150 pounds per square inch, and one designed for the ordinary boiler pressure which has long been in vogue, viz., 80 pounds per square inch. Another feature of the plan was the determination of the efficiency, not only on the comparatively small sizes of pipe which are largely in use, but also on larger pipes, such as are employed extensively in the connection of individual boilers to the mains of a system. The size selected for the small pipe was the 2-inch, and that for the large pipe, the 10-inch. By this means, not only the effects of differences of pressure on the efficiency, but also of differences of size, was determined. No attempt was made to secure coverings having the same thickness of material, as it was assumed that the various manufacturers

adapted the thickness to the requirements of the pipe; and the leading object in view was to ascertain the efficiency of the standard coverings of the various manufacturers, whatever the thickness happened to be. The thickness of each one, however, was carefully measured before application. The thickness after the application, or rather the distance between the outside of the covering and the outside of the pipe, was ascertained by measuring the circumference of each and computing therefrom the average diameter. The thickness of the same covering applied to the two sizes of pipe was different, the covering for the larger pipe being, as a rule, the thicker of the two. To ascertain what effect size alone had upon the efficiency, the thickness of the covering in one case on the 10-inch pipe was reduced by the removal of the outside layers, so as to conform approximately with the thickness of the 2-inch coverings, and its effect was determined for a short trial. The relative efficiency of all the coverings, whether designed for high pressure pipes or for low pressure pipes, was ascertained by running a single test with a uniform pressure of 80 pounds throughout both systems.

6. The tests, as a rule, were made without circulation of the steam other than that produced by the effect of condensation. The drip end in each case was a "dead" end of the pipe, and the steam within was practically dead steam. It has been held that the radiation is not the same in a closed pipe without circulation as it is where the pipe is transmitting the steam at a rapid rate. It is important in a test of this scope that if any doubt exists in regard to the effect of circulation, it should be removed, and if the condensation with steam in circulation is different from that of dead steam, proper allowance should be made for the difference. Under the conditions of actual practice, steam is almost always in circulation, and what is wanted is not the efficiency of coverings where the pipes contain steam in a quiescent state, but those where the steam is moving with considerable velocity, unless the efficiency is proved to be unaffected by circulation. To obtain data on this subject, which would establish the fact as to whether there was a difference or not, the drip ends of two of the pipes were provided with means for establishing a current of steam through the pipe without carrying away any of the water of condensation; and tests were made in each of these pipes under each condition, there being first a period with the steam in its quiescent state, the same as that adopted for the tests in gen-

eral, and then a period immediately following during which a certain measured quantity of steam was drawn off and the test repeated.

7. It may as well be said right here that these comparative runs showed conclusively that there was no difference whatever between the rate of condensation, whether the steam was in circulation or practically quiet; or, if there was a difference, it was so slight as to be within the limit of probable error of measurement. It is to be observed, however, that this statement applies only to the conditions of these tests, for it is no doubt true that if there were no circulation whatever, and no provision made for venting the air brought into the steam, the effect of putting the steam into circulation would be plainly noticeable, owing to the removal of the air which the circulation would induce. These are not the circumstances under which the tests were made, for in every case the air was continuously vented by a suitable opening of the air valve.

The tests determined the rate of condensation, not only under normal conditions of work for a period of several hours each day, but they also determined the total quantity of steam condensed in the pipes from the time the steam was first admitted to the apparatus until the steam was shut off at the close of the test, including that required for warming up the pipes and the coverings from their cold condition.

8. The effect of the various non-conducting materials in reducing the temperature of the outside surface of the coverings was studied to some extent, although not carried far enough to form a basis for any important conclusions. The results of these studies are given in the record for what incidental value they may possess.

9. A test was made on each pipe under the working pressure with the covering removed and the pipe bare, so as to furnish a basis for the determination of the percentage of efficiency. When the 2-inch pipes were tested for this purpose, alternate pipes were tested, so that the radiation of heat from contiguous pipes would not affect the result in any one. When the 10-inch pipes were tested bare, it was necessary to run these in conjunction, there being no means of separating them, and the heat radiated from one served probably to reduce the rate of condensation in the other on the two sides facing each other.

10. After some preliminary tests, the tests on the 2-inch pipes

were commenced on October 3, 1901, and they continued regularly, with the exception of Sundays and a few days in October, until November 9, 1901. On two of the coverings, the total number of days run was 25; on two, 24; on one, 21; on one 20; and on the remaining coverings, and on the bare pipes, from one to eight days.

That no question might be raised as to the influence which locality and surrounding conditions of the various coverings might have on the results of the tests, the following plan was followed as regards the coverings on the 80-pounds section: The four pipes, Nos. 2, 3, 4, and 5, were tested with four different coverings used during the entire time of the tests without change. No. 1 pipe was used as a sort of standard pipe for reference, and the same class of coverings as were applied to Nos. 2, 4, and 5 were applied separately, one after the other, to Pipe No. 1, and each one subjected to a test of comparatively short duration. To a limited extent, the same plan was followed on the 150-pound section of the pipes. By this means, the various classes of covering were compared when applied under precisely the same conditions, with the exception of the temperature and other conditions of the surrounding air. An attempt was made to apply the same class of covering to No. 1 pipe for a short test as that tested on Pipe No. 3; but it was found after application that some parts of the pipe were covered with other material, which made the test useless.

11. Although the coverings were purchased through the regular channels of trade, as already stated, without any notification to the different manufacturers as to the purpose for which they were to be used, the various representatives of the coverings were notified before the tests were completed, and asked to examine the apparatus and the coverings applied, and make any criticisms they saw fit. In reply to these requests, the various interested parties examined the plant and the coverings, and a few suggestions were made pointing out defects of application. These defects were subsequently corrected, but there was no appreciable difference produced in the results, showing conclusively that the coverings had already been well applied. In this connection, it should be said that a careful watch was kept of the various coverings as the test progressed, to discover defects of application due either to the original work, or to the effects of the heat, or to continued use, such as the loosening of the canvas

laps, or the shrinking of the sections from end to end; and whenever such defects were discovered, they were immediately remedied so as always to maintain the coverings in sound condition.

III.—LOCATION AND DESCRIPTION OF APPARATUS.

12. The apparatus was located in an unused part of the basement of the power-house, situated on the south side of the boiler-room portion of the building between the two chimneys. There was a space here of 148 feet in length and 21 feet 6 inches in width, with a height of 8 feet 4 inches to the beams and 10 feet 2 inches to the brick arches of the ceiling, which was admirably adapted to the scheme of tests laid out. Nearly the whole of this space was enclosed by a board partition, which extended to a height of 7 feet from the floor, starting from a point about 12 inches from the floor. The floor was cemented. Along the ceiling on the extreme south side of the room for its entire length, there was an opening about 3 feet 3 inches wide to the floor above, where the boilers are placed. The location of this room and the arrangement of columns, arches, floor-beams, etc., are shown in the accompanying drawings, of which Fig. 322 is a floor plan, Fig. 323 a side elevation looking towards the engine room, and Fig. **324** an end elevation looking toward East River. These drawings also show the location of the test apparatus with reference to the building. They are made from measurements of the building and apparatus taken at the time of the tests.

13. The testing apparatus may be divided into three essential parts: the headers, where the water was separated from the steam and the dry steam was supplied to the testing pipes; the testing pipes themselves; and the drip ends and measuring casks.

The steam was supplied to the apparatus from one of the 520-horse power Babcock & Wilcox boilers on the floor above, which was in use during the time of the tests for the supply of an engine employed for generating electricity about the premises. A 3-inch pipe was laid from the boiler for this purpose to the central distributing separator, *A*. From this point the steam passes through 2-inch pipes to the 2-inch section of the apparatus, entering first the respective headers marked *B* and *C*, header *B* on the left being the low pressure, or 80-pound section, and header

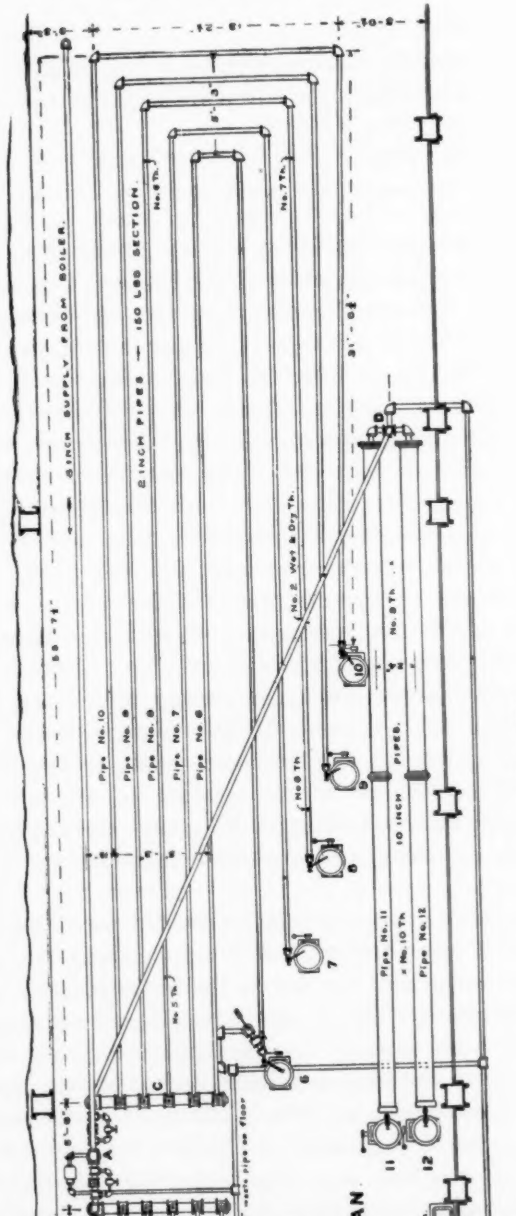
8 INCH SUPPLY FROM BOILER.
2 INCH PIPES — 150 LBS SECTION.
Pipe No. 10
Pipe No. 9
Pipe No. 8
Pipe No. 7
Pipe No. 6
Pipe No. 5
Pipe No. 4
Pipe No. 3
Pipe No. 2
Pipe No. 1
No. 2 Wet & Dry Th.
10 INCH PIPES.
Pipe No. 11
Pipe No. 12
PLAN
A
B
C
D
1
2
6
7
8
9
10
11
12

FIG. 322.

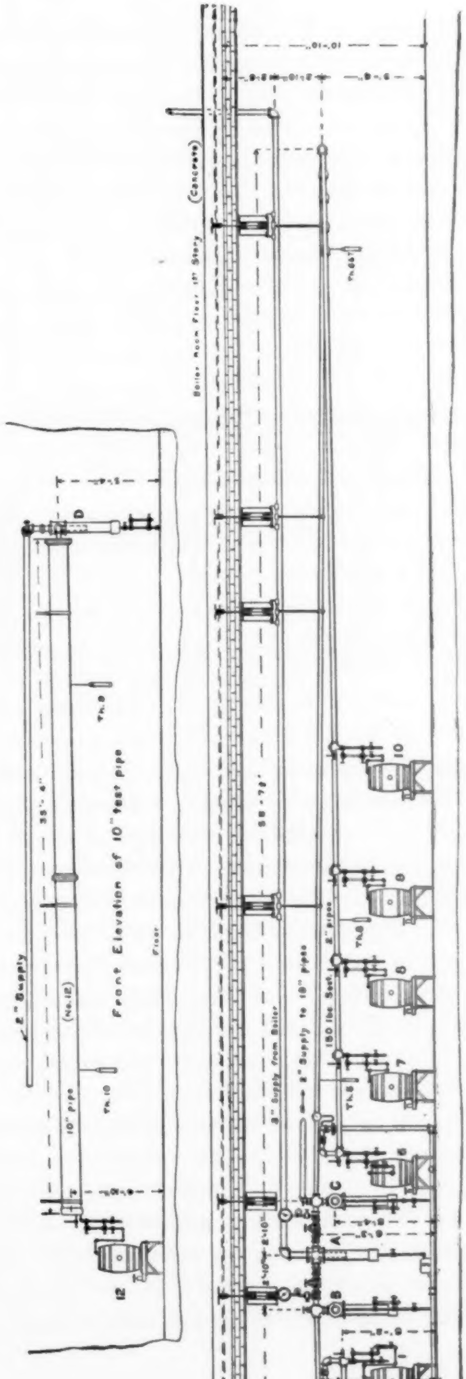
Front Elevation of 10" test pipe
10" pipe
(No. 12)
2" Supply
Floor
3" Supply from Boiler
2" Supply to 10" pipes
150 lbs Sect.
2" pipes
Boiler Room Floor 1st Story
(Concrete)
58'-7½"
35'-4"
D
A
B
C
12
10
9
8
7
6

FIG. 323.

C, the high pressure, or 150-pound section. A continuation of the 2-inch pipe at the right carries the steam diagonally across the room to separator *D*, which furnished high pressure steam to the 10-inch pipes. The drain pipe of separator *A* is carried to an automatic trap which keeps the same free from water. The separators connected with the headers *B* and *C*, as also separator *D*, are drained by pipes having regulating valves which are operated by hand. Gauge glasses attached to the drip pipe at the dead ends of headers *B* and *C*, as also to the drain-pipe of separator *D*, indicate the presence of water, if any collects within.

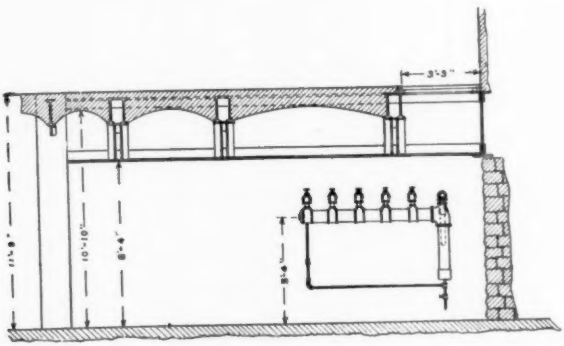

FIG. 324.

Openings for the discharge of steam to the test pipes from the headers *B* and *C* are located at the top of the pipe, thereby insuring to them the dryest portion of the steam contained within. It will be seen that with this arrangement of headers and separators there was no opportunity for free water to obtain access to the test pipes, especially in view of the fact that the quantity of steam supplied was so small that the velocity of the steam at the entrance was inappreciable, and the best possible opportunity was afforded for the deposit of any moisture which might be brought along with the steam from the boiler.

14. The test pipes, which, as already stated, are of the 2-inch and 10-inch size, are arranged in the case of the former in two sections, five pipes in each. They are numbered for reference from 1 to 5 in the 80-pound section, and 6 to 10 in the 150-pound section, these numbers appearing on the plan. The arrangement of the pipes, which are approximately 16 inches apart on each side and all on the same level, is clearly shown in the drawings.

They are each approximately 100 feet in length. In order that the drip ends might be accessible for easy regulation and at the same time to bring into the test the effect of elbows as well as straight runs of pipe, the pipes are arranged to return back in the manner shown and come forward to near the centre of the room. Each one pitches from the header to the drip end, a total distance of 18 inches. The pipes are supported from the iron beams in the ceiling by short hangers. The height of the pipes above the floor for the greater part of their lengths is such that a person may walk beneath them without stooping.

15. The 10-inch pipes, two in number, are designated No. 11 and No. 12. They are approximately 35 feet in length from end to end, and are put together with flanged joints, excepting the caps at the drip ends, which are screwed. One 2-inch angle valve controls the admission of steam to both pipes.

16. On the 2-inch pipes, the drip end consists first of a 2-inch x $\frac{1}{2}$-inch x 2-inch tee arranged with the $\frac{1}{2}$-inch opening looking downward. At the $\frac{1}{2}$-inch outlet is attached a $\frac{1}{2}$-inch pipe, at the lower end of which is a $\frac{1}{2}$-inch valve for drawing off the condensed water. On the side are two $\frac{1}{8}$-inch branches, to which are attached a set of gauge glass fittings. To the outlet of the lower water glass fitting is attached a $\frac{1}{8}$-inch globe valve, which serves as the main regulating valve for the discharge of the water of condensation into the weighing casks. From this valve a $\frac{1}{8}$-inch pipe, increased a little further on to a $\frac{1}{4}$-inch pipe, with the necessary elbows, carries the water into the bottom of the cask. The cask is one holding 20 gallons, resting on Fairbanks scales, the latter registering to one-quarter pounds. The air-vent valves are attached to the 2-inch x $\frac{1}{2}$-inch x 2-inch tee at the drip end of the test pipe at such a point that the bottom of the pipe, which is of the $\frac{1}{4}$-inch size, is $\frac{1}{2}$-inch above the line of the bottom of the 2-inch pipe inside. In the case of the 10-inch pipes the vent pipes, also of the $\frac{1}{4}$-inch size, are attached to the cap at the drip end at a distance of 2 inches above the bottom of the pipe inside.

17. The device used for producing the circulation of steam in pipes Nos. 1 to 6, shown on Fig. 324, consists essentially of an orifice $\frac{1}{2}$-inch in diameter in a plate enclosed between the two parts of a pair of $1\frac{1}{2}$-inch flanges. A $1\frac{1}{2}$-inch valve placed between the orifice and the end of the test pipe enables any desired amount of steam to be drawn off, and its quantity is determined by the pressure shown by the gauge, using the well-known Napier

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formula. Without knowing the exact co-efficient of the orifice, this method gives approximate figures, but an approximation is all that is needed in this case.

18. The dimensions of the various test pipes, embracing length, circumference, total area of surface, and area of surface to which the various materials tested were applied, are given in Table No. 1 at the end of the paper.

IV.—DESCRIPTION OF COVERINGS.

19. The names of the coverings, their locations, and the numbers of the pipes to which they are applied, are given in the following list, the names given being those used for designating the various materials throughout the paper.

80-pound Section, 2-inch Pipes.

	Name of Covering.	No. of Pipe.
1.	New York Air Cell	1
2.	Gast's Air Cell	2 and 1
3.	Carey's Moulded	3 and 1
4.	Asbesto-Sponge Moulded	4 and 1
5.	Asbestocel	5 and 1

150-pound Section, 2-inch Pipes.

6.	Asbesto-Sponge Felt, 59 laminations	6 and 8
7.	Magnesia	7 and 8
8.	Asbesto-Sponge Felt, 48 laminations	8
9.	Asbesto-Sponge Hair Felt, 2 Ply, corrugated	8 and 9
10.	" " " " 3 Ply, plain	9
11.	" " " " 2 Ply, "	9
12.	Asbestos Navy Brand	10 and 6

150-pound Section, 10-inch Pipes.

13.	Watson's Imperial	11
14.	Asbestos Navy Brand	11
15.	Asbesto-Sponge Felt, 76 laminations	12
16.	" " " 66 "	12
17.	Magnesia	12

The composition of the coverings, so far as can be judged by exterior examination, and the leading features of their construction, are as follows:

(1) *New York Air Cell.*—It consists of alternate layers of plain and corrugated asbestos sheets, the corrugations of which run lengthwise of the pipe.

(2) *Gast's Air Cell.*—This covering is four-ply and is similar in general features of construction to the New York Air Cell. It differs from that covering in having thicker sheets of asbestos.

(3) *Carey's Moulded.*—A solid white mass of uniform texture, which has the appearance of being a mixture of plaster of Paris and asbestos fibre, the former predominating, and it is moulded in the required form for application to the pipes.

(4) *Asbesto-Sponge Moulded.*—A compact white mass of uniform texture of what appears to be asbestos fibre and plaster of Paris, the latter predominating.

(5) *Asbestocel.*—Concentric alternate layers of plain and corrugated asbestos paper, the corrugations passing circumferentially around the pipes.

(6) *Asbesto-Sponge Felt,* 59 *Laminations.*—This consists of superimposed layers of asbesto-sponge paper, held in place by an adhesive compound. The paper is composed of asbestos fibre and fine particles of sponge, the latter appearing in numerous flakes distributed throughout the body of the material.

(7) *Magnesia.*—A compact white mass moulded to the shape of the pipe, which appears to be a combination of carbonate of magnesia and asbestos fibre. The outside is finished with canvas.

(8) *Asbesto-Sponge Felt,* 48 *Laminations.*—This is the same class of covering as the No. 6 above described, the only difference being in the number of sheets of asbesto-sponge, which averaged 48, the lowest number in any one section being 23, and the highest 60.

(9) *Asbesto-Sponge Hair Felt,* 2-*Ply, Corrugated.*—This covering consists of one plain and one corrugated asbestos sheet, with corrugations running lengthwise of the pipe, then, a layer of asbesto-sponge hair felt, the latter being composed of a mixture of asbestos fibre, sponge, and hair felt, the asbestos predominating.

(10) *Asbesto-Sponge Hair Felt,* 3-*Ply, Plain.*—It consists of a sheet of asbestos, then three layers of asbesto-sponge felt, alternating with three layers of resin-sized paper, the outside finish being canvas.

(11) *Asbesto-Sponge Hair Felt,* 2-*Ply, Plain.*—Similar to No. 10, just described, with the exception that two layers of felt and resin-sized paper are employed, instead of three.

(12) *Asbestos Navy Brand.*—This covering has an inner layer or crust of asbestos, surrounded by asbestos fibre of a more or less felted texture, and an outer layer of asbestos.

(13) *Watson's Imperial.*—This is composed of layers of asbestos paper, each of which is made up of one plain sheet and one indented sheet. The number of sheets of plain paper in the covering tested was 7, and of indented paper, 6.

(14) *Asbestos Navy Brand.*—Similar, except in thickness, to No. 12.

(15) *Asbesto-Sponge Felt*, 76 *Laminations.*—Similar, except in thickness and the number of laminations, to No. 6.

(16) *Asbesto-Sponge Felt*, 66 *Laminations.*—Similar, except in thickness and the number of laminations, to No. 15.

(17) *Magnesia.*—Similar, except in thickness, to No. 7.

20. The dimensions of these coverings, embracing the thickness before application, the circumference of the coverings after application, the calculated thickness after application, that is, the distance between the outside of the covering and the outside of the pipe, weights of each covering per section 36 inches long, and the area of the outside surface, are given in Table No. 2 at the end of the paper.

21. The various coverings subjected to the test were applied to the 2-inch pipes, starting with the end of the 2-inch angle valve at the header, and ending at the end of the 2-inch x $\frac{1}{2}$-inch x 2-inch tee at the drip end. The 2-inch angle valves on the headers, the pipes composing the drip ends, exclusive of the gauge glass and the brass fittings which hold the glass, and exclusive also of the $\frac{1}{8}$-inch and $\frac{1}{4}$-inch pipes and fittings belonging to the discharge pipes and air vent pipes, as also the $\frac{1}{2}$-inch valve at the bottom of the main drip pipe, were covered with asbestos fire felt one inch thick. The 1 $\frac{1}{2}$-inch extensions leading from the top of the 2-inch x $\frac{1}{2}$-inch x 2-inch tee at the drip ends of Nos. 1 and 6 pipes, were also covered with asbestos fire felt one inch thick. The headers and separators were covered with hair felt. On the 10-inch pipes, the materials subjected to the test were applied solely to the straight run of pipe between the shoulders of the flanges in the first length, and between the shoulder of the flange and the end of the cap at the drip end in the second length. The separator and the pipes leading to the flanges at the head of the 10-inch pipes, the flanges themselves at the head

end, and the flanges at the centre, together with their hubs, were covered with hair felting two inches thick. The cap at the drip end, together with the pipes composing the drip apparatus, with the exception of the water glass and its fittings, the $\frac{1}{8}$-inch and $\frac{1}{4}$-inch pipe and fittings for drawing off the water, and those for venting the air, were covered with asbestos fire felt one inch thick. When the coverings were changed, as was done on Pipes 1, 6, 8, and 9, as also on Pipes 11 and 12, the hair felt and fire felt coverings referred to were left undisturbed.

22. The coverings on Nos. 2, 3, 4, and 5, 80-pounds section, and on Nos. 7 and 10 of the 150-pounds section, were kept in use without change through the entire period of the tests. The coverings applied to No. 1 pipe, one after the other, were samples of New York Air Cell, Asbestocel, Asbesto-Sponge Moulded, Gast's Air Cell, and Carey's Moulded. (See reference to this in paragraph 10.) On No. 6 pipe, high-pressure section, the coverings applied one after the other were Asbestos Navy Brand, Magnesia, and Asbesto-Sponge Felt, 59 laminations. On Pipe No. 8, the coverings applied, one after the other, were Asbesto-Sponge Felt, 48 laminations, Asbesto-Sponge Felt, 59 laminations, Magnesia, and Asbesto-Sponge Felt, 2-Ply, Corrugated. The coverings applied to No. 9 pipe were Asbesto-Sponge Hair Felt, 2-Ply, Plain, and the same, 3-Ply, Plain. Those applied to No. 11 pipe were Asbestos Navy Brand and Watson's Imperial, and those to No. 12, Magnesia, Asbesto-Sponge Felt, 76 laminations, and the same, 66 laminations.

The coverings applied to Pipes Nos. 6 and 8, between October 22d and October 28th, being Magnesia on the former and Asbesto-Sponge Felt, 59 laminations, on the latter, were interchanged during the evening of October 28th, and the same coverings continued to be used in their new locations.

23. The sections of covering in all cases were approximately 36 inches in length, whether applied to the 2-inch pipes or the 10-inch pipes. The canvas finish has a loose flap overhanging one edge of the covering where it is pasted, by means of which the covering is secured in its place, the overlapping part being covered with paste which adheres to the other half and makes a continuous finish. Thin metal bands are finally applied, two or three to each section, in order to further secure the covering and hold it in place. Where the sections butt together at their ends, the canvas also overlaps, and is likewise secured with paste to the

next section, making a continuous covered surface and sealing the openings between the sections.

24. The costs of the various coverings are given in Table No. 3, at the end of the paper. These costs were determined and furnished by the mercantile house through whom the coverings were purchased, and they represent the cost of the same to the consumer, figured on the same comparative basis of charge. They may not represent the exact cost of any of the coverings named for any special locality or special plant, for the cost in special cases depends upon a variety of circumstances, and these circumstances are seldom the same in one case as in another. They do represent, however, the relative cost of the coverings under the same surrounding conditions, as nearly as these can be ascertained. The costs given in the table embrace the cost per running foot, not including the cost of application, the cost per running foot, including application, and the cost of coverings applied to pipes having an exterior surface of 10,000 square feet. The length of pipe having the surface area mentioned is found by dividing 10,000 by the circumference of the two sizes of pipe, which, in the case of the 2-inch pipes, is .628 feet, and in the case of the 10-inch pipes, 2.811 feet. For the 2-inch pipes, the length is 15.924 feet, and the 10-inch, 3.535 feet. The cost of applying the coverings is taken at four cents per running foot, for all the 2-inch coverings, except the Asbesto-Sponge Hair Felt, which is taken at five cents per running foot. The cost of applying the covering to the 10-inch pipe is taken at five cents per running foot.

V.—HOW THE TESTS WERE MADE.

25. The tests were for the most part complete runs of one day's duration, starting with pipes and coverings cold and the pipes empty, and ending with the steam shut off and the pipes completely drained. A representative test was made as follows: The test was started at 8.05 A.M., at which time the steam was turned on the apparatus by opening the valves leading to the two headers. The pressure was allowed to rise gradually, being 20 pounds in each header at 8.12 A.M., seven minutes after starting, and reaching the working pressure at 8.20 A.M., fifteen minutes after starting; the casks having been partly filled with cold water previous to the start, and the weights carefully observed. The first readings of the scales were taken at 8.20 A.M., and at the same time

a complete record was made of the steam pressure in each header, the temperature of the steam shown by the thermometers in oil wells immersed in the headers, the temperature of the steam shown by the thermometers in the drip chambers of Nos. 1 and 6 pipes, and the various temperatures as indicated by the air thermometers. The pressure in each section was then maintained as nearly constant as practicable, and the readings of the scales, gauges and thermometers were taken every half hour until the close of the test. This occurred at 4.40 P.M., and at that hour the valves admitting steam to the headers were shut. The pressure then gradually fell on both sides, until, at 4.57 P.M., it became zero, and the drip valves were opened wide and all the water drained out. The final readings of the weights were then taken. During the progress of the tests, two workmen were employed, one on each side, to regulate the discharge of water from the drip chambers, maintaining the level as near as practicable at a fixed point, as shown in the water glass. When the casks had become filled to such a point as to require emptying, which always occurred once during the progress of the day's run, the discharge valve was closed and the water allowed to back up into the end of the test pipe. Meanwhile, the weight was taken and the cask emptied and filled anew about half full of cold water. The weight was then again taken, and the discharge valve opened, bringing the water-level back to its normal position. When the regular time arrived for taking the readings, the mode of procedure consisted in shutting off the discharge valve of No. 1 pipe at the exact time given in the record. Fifteen seconds later, the discharge valve on No. 2 pipe was shut off; thirty seconds later, No. 3 pipe was shut off; forty-five seconds later, No. 4; and so on through the whole number, each shutting off occurring fifteen seconds later than the preceding one. As soon as the valve was shut, the weight on the scales was taken and recorded, and when this was done, the valves were all again re-opened and adjusted to the normal position. In this way, intervals between successive readings of the weights were always the same, although they were not all taken at precisely the same instant—a matter which it was impracticable to accomplish. The data of the tests were all taken by the writer, assisted by Mr. Joseph C. Schaeffler, junior member of the Society, both of whom were in constant attendance throughout the tests.

26. The valve admitting steam to the 150-pound section of the apparatus was kept wide open, and the pipes subjected to the

boiler pressure, which was carried as nearly as practicable at 150 pounds. The valve admitting steam to the 80-pound section was opened sufficiently to obtain the desired pressure, and if the pressure changed, the valve was changed accordingly.

27. The scales used were of the Fairbanks make, reading to one-quarter pound. No attempt was made to read closer than one-half pound, except at the beginning and end. Each scale was standardized by means of sealed weights. The gauges were standardized by comparing with the dead weight testing apparatus. The thermometers used in the headers and drip chambers of No. 1 and No. 6 pipes, also those for showing the humidity of the air (wet and dry bulb thermometers), as also those applied to the outside of the coverings, were manufactured by Henry J. Green, of Brooklyn. The thermometers used for showing the temperature of the air were the ordinary air thermometers, enclosed in black japanned cases. These were standardized by comparison with those of Henry J. Green's make. The location of the various gauges and thermometers is shown on Figs. 1, 2, and 3. The thermometers showing the temperature of the air were suspended from Pipes No. 3 and No. 8, and midway between Nos. 11 and 12 the bulbs being 24 inches below the pipe.

28. At various times during the progress of the work, an attempt was made to measure the velocity of the air currents, if there were any currents, at different points about the test room. A delicate anemometer, made by Short & Mason, of London, was used for this purpose. The instrument was held in various positions in the neighborhood of the various pipes, so as to show the current which might be moving in any direction around the pipes, either vertically or horizontally. As a result of these observations, which were made a sufficient number of times, and at a sufficient number of points to be thoroughly satisfactory, it was found that there was an entire absence of any current of air of sufficient force to move the anemometer vane. The instrument was absolutely motionless at every point. It is not held that this is a proof that there were no currents of any nature within the test room, because the instrument did show that currents existed on the floor of the room, at the openings under the wooden partition, and at points in the upper part of the room over the partition, but in the region about the pipes themselves, which were several feet above the floor, such currents as existed at the points named wholly disappeared.

29. The thermometers used for showing the temperature of the outside surfaces of the coverings were laid flat on the upper surface, and the bulbs covered with hair felt 2 inches thick. These thermometers were used only on some of the tests during the closing days of the work. In this connection an attempt was made to ascertain the effect of the heat radiated from the coverings, in warming pans of water supported on the outside, the same being carefully protected all over by a covering of hair felt 2 inches thick. These pans were 9 inches long, $4\frac{1}{2}$ inches deep at the shallowest point, and 5 inches wide. The ends were semicircular, and the lower surface was made semi-circular in form so as to fit in some degree the curvature of the covering. The pans were filled with the same quantity of water, being in the first place cold water gradually heated, and in the second place, water which had already been heated. These were applied only to pipes on the 80-pound section. Starting with cold water on the test of October 28th, the pans became heated to the following temperatures at the close of the run:

No. 2. Gast's air cell	151.5 degrees.
" 3 Carey's moulded	136.5 degrees.
" 4. Asbesto-sponge moulded	138.5 degrees.
" 5. Asbestocel	136.5 degrees.

Starting the next day with water heated to 149 degrees, the temperatures at the end of the run were as follows:

No. 2. Gast's air cell	152.5 degrees.
" 3. Carey's moulded	144.0 degrees.
" 4. Asbesto-sponge moulded	146.0 degrees.
" 5. Asbestocel.	143.0 degrees.

On four succeeding days, with preliminary heating, the temperatures at the close of the run averaged as follows:

Number of Pipes....	2	3	4	5
		Name of Covering.		
	Gast's Air Cell.	Carey's Moulded.	Asbesto-sponge Moulded.	Asbestocel.
Averages..........	155.4 deg.	146.8 deg.	145.6 deg.	142.8 deg.

On four succeeding days, without preliminary heating of the water in the pans at the start, the temperatures at the end of the run averaged as follows:

Number of Pipes....	2	3	4	5
		Name of Covering.		
	Gast's Air Cell.	Carey's Moulded.	Asbesto-sponge Moulded.	Asbestocel.
Averages..........	152.1 deg.	145.4 deg.	142.5 deg.	141.3 deg.

The temperature of the outside of the coverings shown by the thermometers on the high pressure pipes at the end of eight runs, averaged as follows :

Number of Pipes....	6	7	8	9	10
	Name of Covering.				
	Asbesto-Sponge Felt, 59 lamina's.	Magnesia.	Magnesia.	Asbesto-Sponge Hair Felt 3-ply.	Navy Brand.
Averages....	196.9 deg.	196.9 deg.	195.3 deg.	202.8 deg.	208.6 deg.

The average temperatures of the outside of the coverings on pipes No. 11 and 12 at the end of several runs, were as follows:

Number of Pipe.............	11	12
	Name of Covering.	
	Navy Brand.	Asbesto-sponge Felt, 76 laminations.
Averages for two days........	224 degrees.	211 degrees.
	Watson's Imperial.	
Averages for four days........	238 degrees.	204.5 degrees.

The readings of these thermometers were in some cases found to change when the bulb of the thermometer was moved a short distance to a new position. The effect of covering the pans and preventing radiation from their surfaces and from the surface of the water which they contained, was found also to be exceedingly marked; and the conclusions drawn are that slight differences in the thickness and arrangement of the covering may have had a considerable effect upon the temperature of the water within. The reliability of the indications of these thermometers in showing the relative non-conducting properties of the various coverings, is, therefore, open to some question. With this explanation, the readings are here reported for the value they may possibly possess.

30. The test for determining the effect of the circulation of the steam in Nos. 1 and 6 pipes was made by observing the rate of condensation for a certain period of time each way, the test in each case being started after the pipes and the coverings had been thoroughly heated, and the apparatus had attained a normal condition of work. The test was made, first, with the steam shut off from the orifice, and then immediately followed by a suitable run with the valve opened enough to maintain a pressure of 15 pounds at the orifice. At this pressure, it is estimated that the amount of steam passing through each of the 2-inch pipes was approximately 300 pounds per hour.

31. To determine what proportion of the entire condensation was due to that condensed in the drip end of the pipe, a test was made on No. 6 pipe with this end in view. The test was made without changing the arrangement of the pipe, excepting to lift the drip end to such a point that the test pipe should incline away from the drip end, and, therefore, prevent condensation from that portion of the pipe passing into the measuring apparatus. It was found that the rate of condensation of this end of the No. 6 pipe amounted to six-tenths of a pound per hour.

From the results of this test, the corrections for all the other drip ends have been made. The area of the surface of the drip ends of Nos. 7 to 10 pipes is six-tenths of the area of the surface for the No. 6 pipe; and the rate of condensation in those pipes is taken at the pro rata value, or $\frac{6}{10}$ of $\frac{6}{10}$ equals $\frac{36}{100}$ pounds per hour. The test of the same covered pipe under the two working pressures showed that at 80 pounds pressure, the condensation was 84 per cent. of that which occurred at 150 pounds pressure. The correction for Pipes Nos. 1 to 5 are, therefore, found by taking 84 per cent. of the correction for the corresponding pipes, Nos. 6 to 10. The corrections are summarized as follows:

No. 1	.5
" 2	.3
" 3	.3
" 4	.3
" 5	.3
" 6	.6
" 7	.36
" 8	.36
" 9	.36
" 10	.36

On the Nos. 11 and 12 pipes, in making the corrections for the condensation due to the flanges and supply pipes which were covered with hair felt, and for the drip caps, which were covered with Asbestos Fire Felt, and for the drip ends, which are the same as those on the 2-inch pipes, it is assumed that the hair felt covered surfaces condensed $\frac{1}{10}$ of a pound per square foot per hour, the drip cap $\frac{13}{100}$ of a pound per square foot per hour, and the drip chamber the same as Nos. 7 to 10 2-inch pipes, or $\frac{36}{100}$ of a pound per hour. These, collectively, amount to 1.55 pounds.

32. That there might be no question as to the character of the steam supplied to the test pipes, one of the writer's calorimeters was applied to the right-hand header at a point between pipes Nos.

9 and 10, and the dryness of the steam ascertained by actual test. This test, which was confined to a single day's observation, showed that the steam was commercially dry, the actual percentage of moisture being .25 of 1 per cent.

VI.—MANNER OF WORKING OUT THE FINAL RESULTS.

33. The final results of the trials are based on the rate of condensation which occurred when the coverings were well heated and the apparatus was working under normal conditions. The entire duration of the various tests—that is, the period elapsing between the time of turning on the steam and the time of taking the last weight—was usually about nine hours. Of this period, about three hours were required for heating up the pipes and coverings to the normal condition, and in cooling them down at the end of the test; leaving for the period of normal work, a run of about six hours' duration. It is upon this run of six hours, and in a few cases a shorter period, that the final results are based. In some cases, the tests made when the covering was first applied are omitted, for the reason that there is evidence in the continued falling off of the rate of condensation from day to day that the coverings had not become thoroughly heated and dried out after application. The tests from day to day were made under different conditions regarding the temperature of the surrounding atmosphere and average steam pressure. That these differences of conditions might be properly allowed for, and the results brought down to a standard, the rate of condensation as shown by the data of the test has been reduced to the number of heat units lost for each square foot of surface of the bare pipe per hour, divided by the difference in temperature between the steam inside the pipe and the air surrounding the covering. In making this computation, the rate of condensation as determined from the data is corrected for the effect of the drip ends, using the amount pointed out in the previous section and using the area of pipe surface given in the last column of Table No. 1. The temperature of the steam within the pipe has been found from tables of saturated steam, being the temperature corresponding to the observed average pressure. The temperature of the water discharged from the drip chambers has been assumed to be constant for all the pipes in the 150-pound section, and likewise constant for all the pipes in the 80-pound section, being the averages of

the temperatures observed for the No. 1 and No. 6 pipes. For the 80-pound section, the constant temperature assumed is 305.1 degrees, and for the 150-pound section, 339 degrees.

34. To bring the results in heat units lost per unit of temperature difference into a more practical form for a steam user, the amount of coal required to furnish the loss of heat which these quantities represent has been computed for 10,000 square feet of surface for a continuous run of 24 hours per day for a year of 365 days. It is assumed that the coal is of such a quality that one pound furnishes to the steam 10,000 heat units (or what is called in the 1899 Code of Boiler Tests "standard" coal), and the weight in pounds is converted into tons by dividing the number of pounds by 2240. For the same purpose, the cost of the coal required for such a plant, operated for the time named, is also computed, assuming that the coal costs $4 per ton. The temperature of the air for these computations is assumed to be 60 degrees, and the pressure of the steam in the two sections, 80 pounds and 150 pounds respectively. Under these circumstances, the difference in temperature between the steam and the surrounding air in the case of the low pressure pipes, is 263.6, and in that of the high pressure pipes, 305.6. The number of tons of coal computed from the heat units lost per unit of surface per hour per degree difference of temperature is readily found by the use of a simple formula as follows:

80-pound pipes: Tons of coal per year = 1031 × British thermal units.
150-pound pipes: Tons of coal per year = 1195 × British thermal units.

35. In working out the final results of the tests made on the 2-inch bare pipes, the corrections for the covered drip ends on the pipes are those referred to in paragraph 31, the portion of the surface made bare being simply the part which was covered by the materials subjected to test. On the 10-inch pipes, the correction made is less than that on the covered pipes, owing to the fact that the hair felt used on the centre flanges on the covered pipes was removed when the pipes were tested bare. The correction used is 1.25 pounds per hour.

VII.—DATA OF THE TESTS.

36. The data of the tests are so voluminous that it has not been thought desirable to reproduce them in full in this paper. The

author will be glad to discuss them in detail with any members specially interested.

Table No. 4 presents a summary giving the average differences of temperature and the hourly rates of condensation for the 6-hour periods of normal condition.

The charts, Figs. 325–336, give the hourly rate of condensation

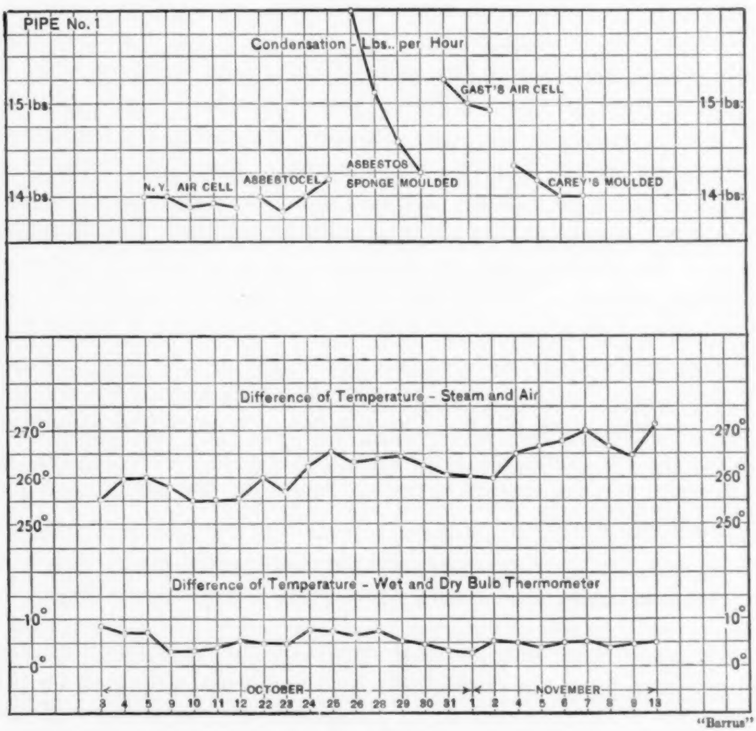


FIG. 325.

for the 6-hour periods of normal conditions; the difference between the temperatures of the steam and the air; and the difference between the temperatures shown by the wet and dry bulb thermometers. Figs. 337 and 338 show the average pressures; the average temperature of the steam corresponding to the pressure; the average air temperature; and the difference between the temperatures of steam and air for the 6-hour period of normal conditions.

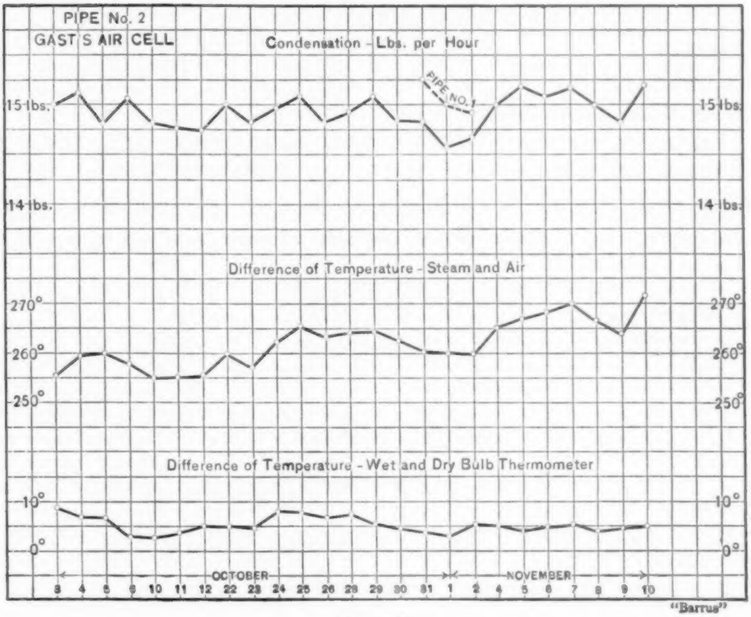


FIG. 326.

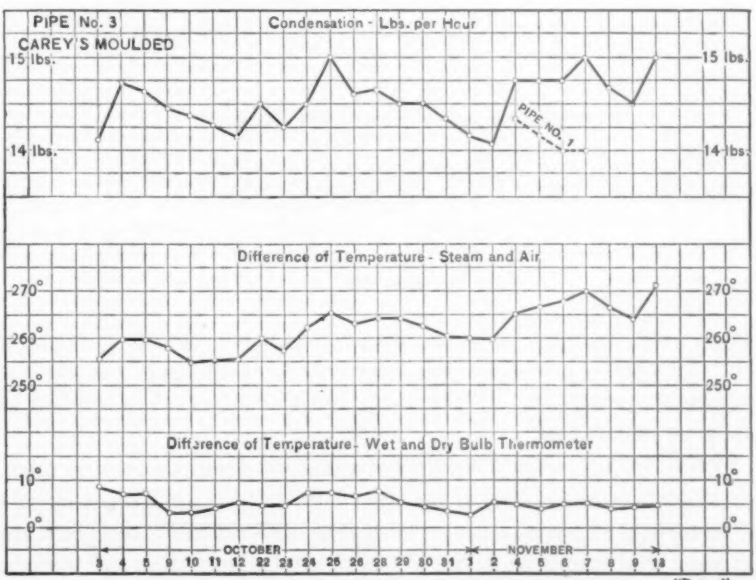


FIG. 327.

VIII.—DEDUCTIONS AND RESULTS.

37. The deductions and final results based on the previous tables are given in Tables 5 to 11, inclusive.

Table No. 5 presents the net area of the bare pipe; the net condensation per hour for the 6-hour periods of normal conditions; and the number of heat units lost per degree difference of temperature per square foot of surface of bare pipe per hour; the

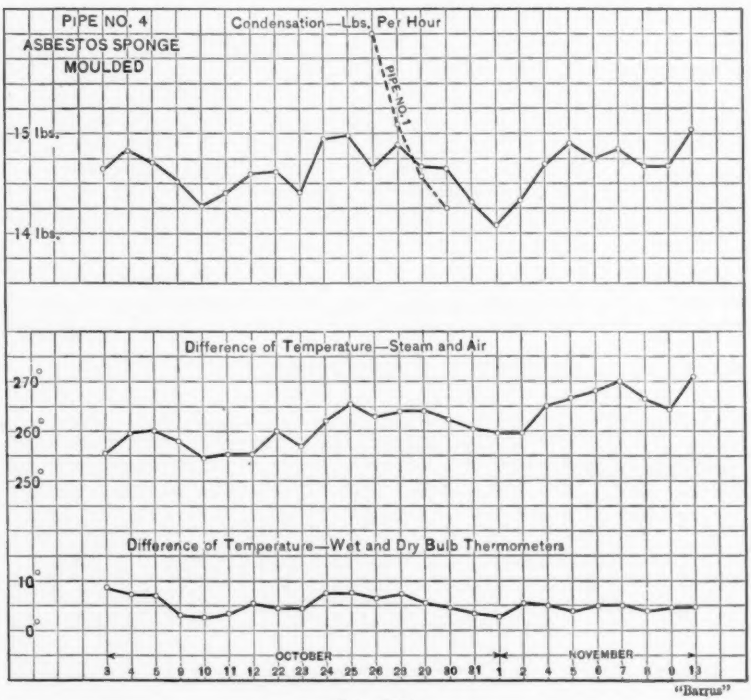


FIG. 328.

latter being computed in the manner pointed out in paragraph 33. This table gives the deductions as to heat unit loss for the various coverings on all the tests, whether they were applied to one pipe or another.

Table No. 6 presents the final deductions from the whole number of tests as to the loss of heat per hour with the different classes of covering, expressed for one degree difference of temperature between the steam and the air and one square foot of outside surface of the pipe. In the case of the low-pressure coverings,

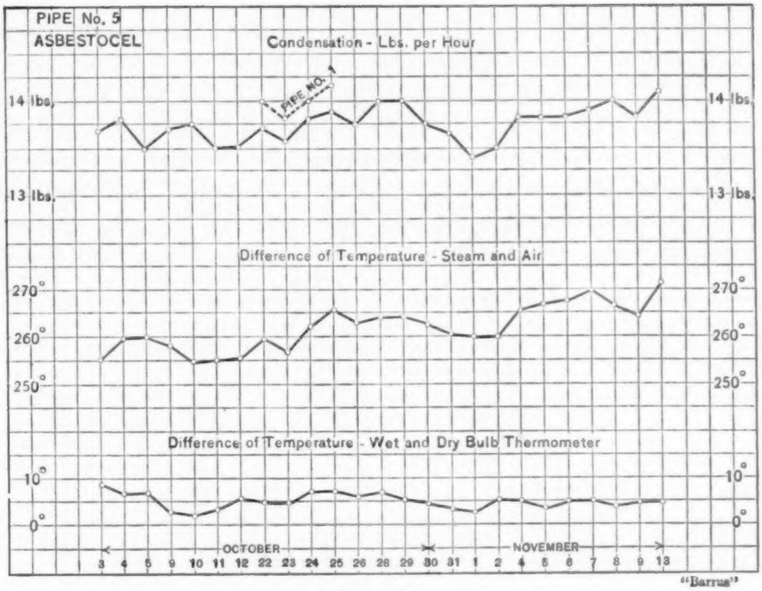


Fig. 329.

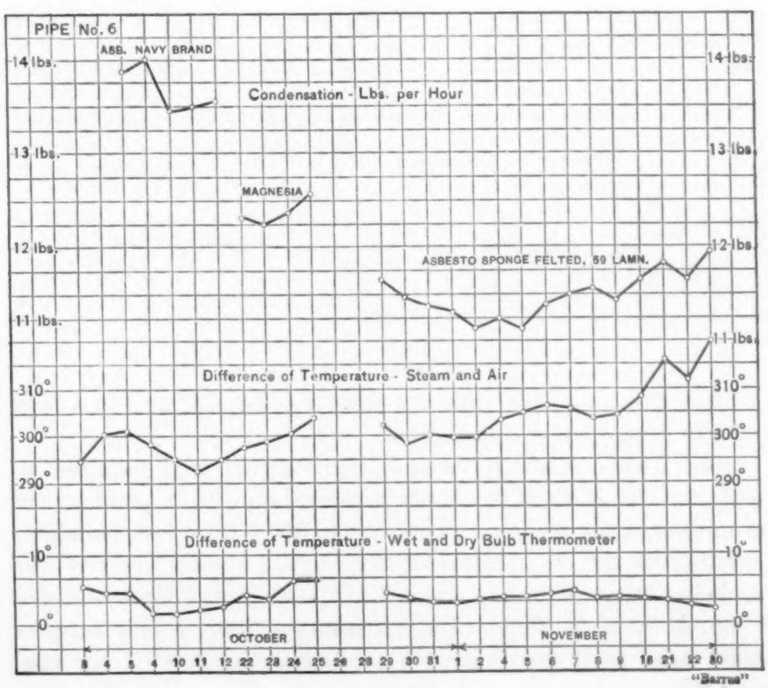


Fig. 330.

these are the figures deduced from the results of the tests on Pipes 2, 3, 4, and 5, which apply to the long period of continued service. Those deduced from the short runs of the various coverings applied to Pipe No. 1 (with the exception of Carey's Moulded, which is inconclusive for the reasons elsewhere stated), are so close to those obtained on the long runs as to be simply confirmatory of the figures selected. For the same reasons, the final deductions regarding Magnesia and Asbestos Navy Brand are those

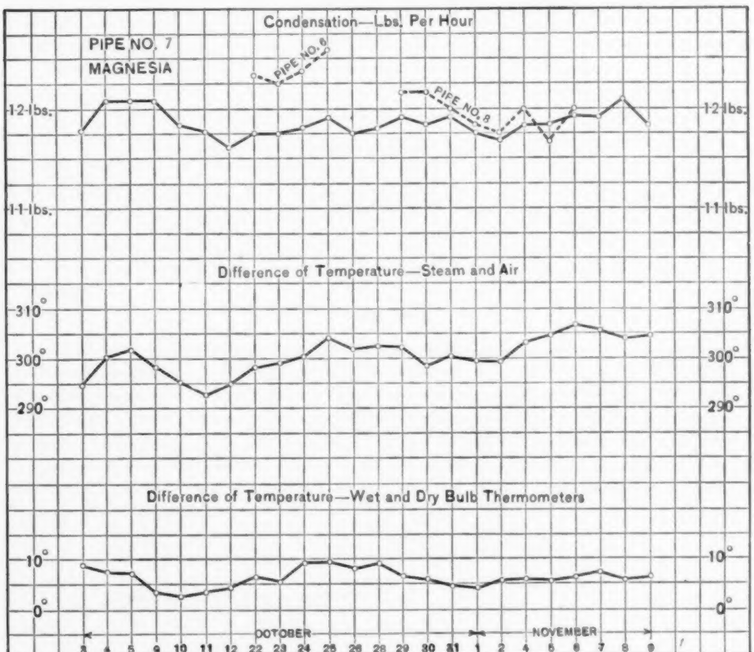


FIG. 331.

found on the long runs with the coverings applied to Pipes Nos. 7 and 10 of the 150-pound section.

Table No. 7 gives the weight and cost of coal required to supply steam sufficient to maintain the pressure in a plant where the surface of the pipe has an area of 10,000 square feet, assuming a continuous run of one year of 365 days, 24 hours per day, the coal being what is termed "standard" coal in the Code of Rules of the A. S. M. E. Boiler Test Committee, 1899, which supplies 10,000 heat units per pound to the boiler, the cost of the coal being taken at $4 per ton of 2,240 pounds. This table also gives

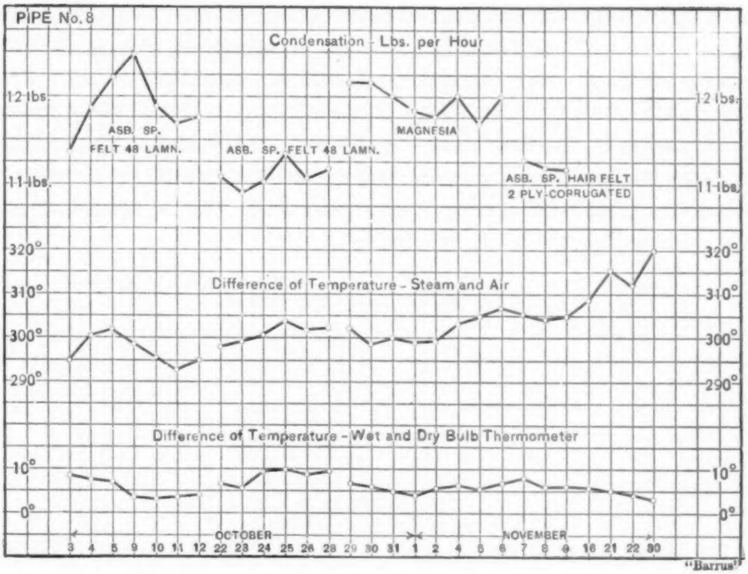


FIG. 332.

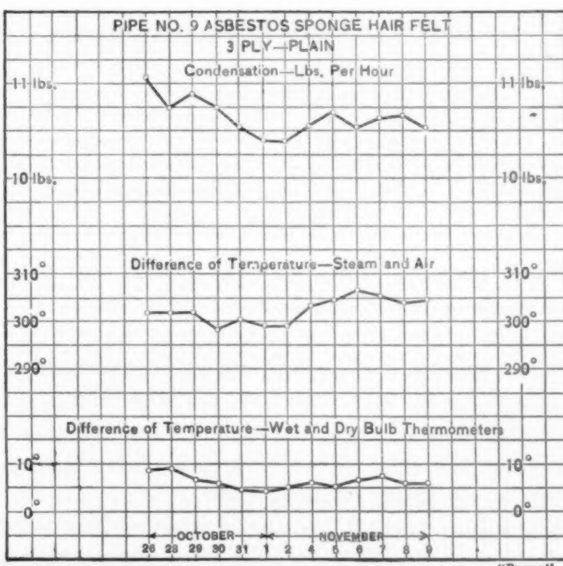


FIG. 333.

the relative cost of the coal required, and, at the same time, the relative loss of heat from the various coverings expressed in percentage, the one showing the least cost in each class being taken at 100. This table is based on the heat units referred to in Table No. 6, and it is assumed that the pressure of the steam on the low-pressure section is 80 pounds per square inch, and on the high-pressure section 150 pounds per square inch, the temperature of the surrounding air being 60 degrees.

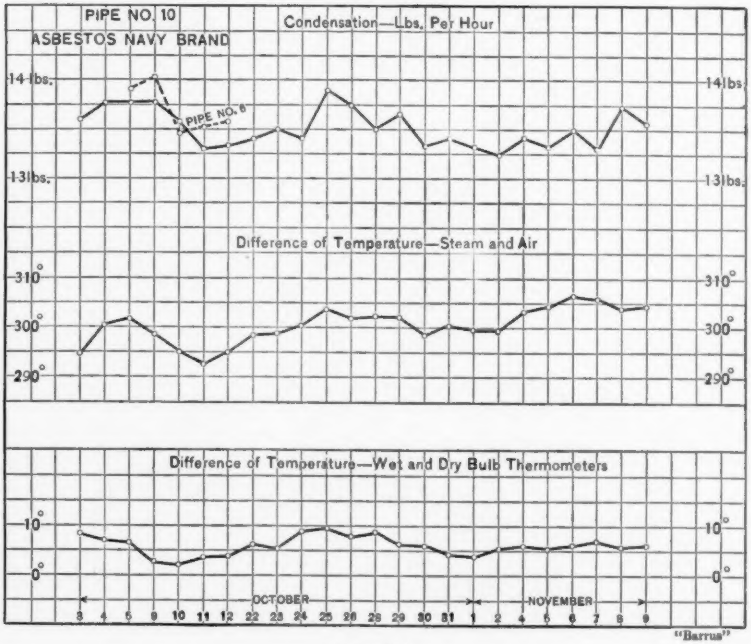


FIG. 334.

Table No. 8 presents what may be termed the relative commercial value of the coverings, deduced from Tables Nos. 3 and 7, being in each case the cost of the covering at the end of five years' continuous use, embracing the first cost of the covering; the cost of coal required for the entire period; and the interest charges on the entire investment at 5 per cent., compounded annually. This table also gives the relative costs in each class expressed in percentage, the lowest being taken at 100.

Table No. 9 gives the efficiencies of the various coverings referred to the heat radiated from bare pipes, these being expressed in percentage. The figures given are computed by subtracting

the heat lost per degree difference of temperature per square foot of surface per hour pertaining to the covered pipe, from that pertaining to the bare pipe in the same class, as given in table No. 6, and finding the percentage which the difference bears to the heat radiated from the uncovered pipe.

Table No. 10 presents a comparison between the losses in heat units from the same coverings applied to the 2-inch and

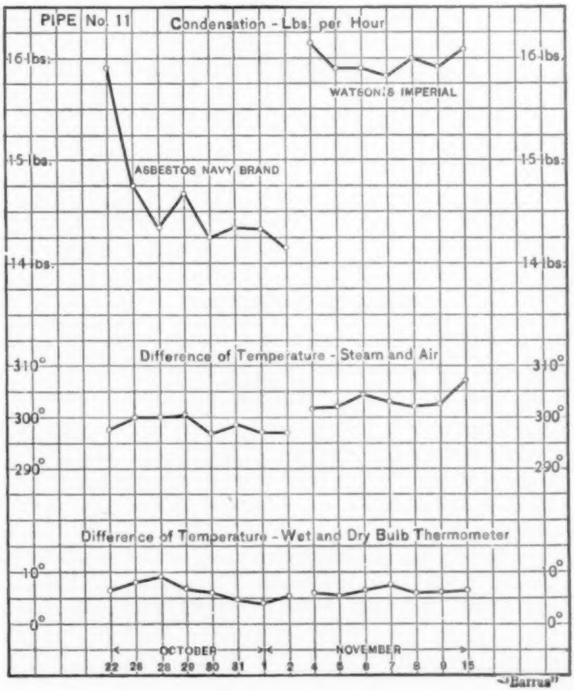


FIG. 335.

10-inch pipes at 150 pounds pressure. These losses are based not on the surface of the bare pipe, as given in the previous tables, but on the outside surface of the covering for each size of pipe.

Table No. 11 presents a comparison of the efficiencies of some of the coverings applied to the 150-pound section, not only at 150 pounds pressure, but also at 80 pounds pressure; these being the same as the efficiencies given in table No. 9, but arranged in parallel columns.

IX.—CONCLUSIONS.

38. The data and results of the tests are given in such detail that any interested reader can draw his own conclusions. Those of the writer may be summed up as follows:

39. *First.* It has long been known that the most efficient covering, as regards merely the non-conducting properties, is hair felt;

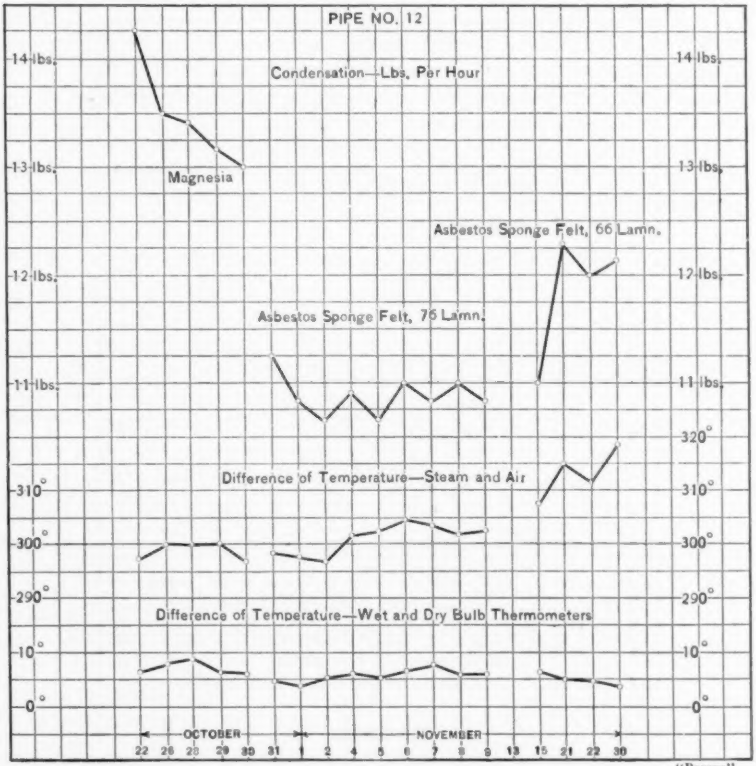
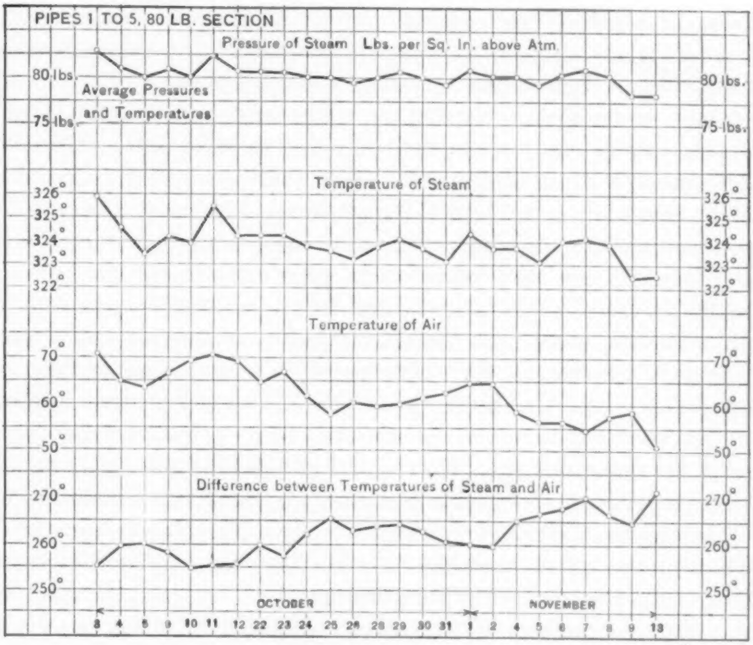


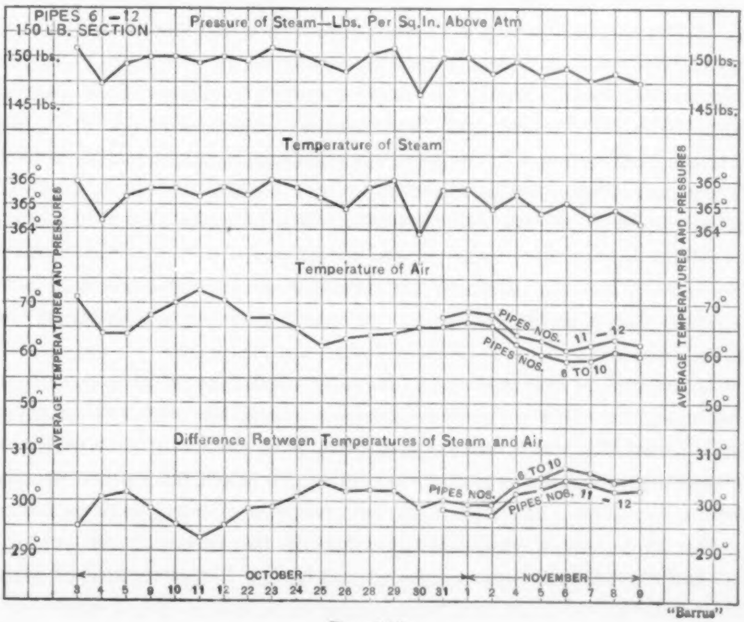
FIG. 336.

and it is not surprising that the best result obtained on these tests is that of a covering which very closely resembles hair felt in its physical characteristics. This is "Asbesto-Sponge Hair Felt," so-called. The reason for the superiority of hair felt, which is commonly accepted, is the fact that this covering divides up and entraps the air which it contains in a better manner than any other material commonly used, and it is the non-conducting prop-



"Barrus"

FIG. 337.



"Barrus"

FIG. 338.

erties of confined air upon which the efficiency of the covering depends, quite as much as upon the material of which it is composed. Hair felt is not a satisfactory covering, however, on account of its want of durability. The mixture of hair felt and asbesto-sponge used on the tests, does not seem to possess this objectionable feature, owing to the fact that so large a proportion of the material (more than three-quarters) is asbestos fibre, which is indestructible. The writer has seen some of this covering which had been in use four years on a pipe containing 150 pounds steam pressure, and no evidence of objectionable charring or other deterioration was visible. The next highest efficiency shown on the tests is that obtained with asbesto-sponge felt, 59 laminations, and the same reason for the superior result applies in this case as in that just referred to, that is, that the arrangement of the covering in thin sheets placed concentrically about the pipe is a superior method of securing an efficient distribution of the confined air held by the covering. This is further exemplified in the effect produced by increasing the number of layers of air with practically the same thickness of material, as may be seen by a comparison of the results obtained with this covering, first, with 48 laminations, or thicknesses of material, and then with 59 laminations, applied to 2-inch pipes. The difference in the radiation in these two cases is about 8 per cent. Although this difference is in a small degree accounted for by a slight difference in the thickness of the two coverings (that with 59 laminations being $1\frac{1}{8}$ inches, and that with 48 laminations, 1 inch), the increased efficiency of the greater number of laminations is still far beyond that due to difference of thickness. The effect of the presence of sponge distributed throughout the sheets of asbestos, of which the laminations are composed, no doubt contributes some share to the efficient entrapment of air beyond that produced by the mere use of thin concentric sheets laid one upon the other.

40. *Second.* It appears that in the so-called "Air Cell" coverings, which were tried on the low-pressure pipes, the one which gives the highest efficiency, viz., Asbestocel, is a covering in which the corrugations which form the air cells extended circumferentially around the pipe. In the other coverings, the corrugations forming the air cells extended lengthwise of the pipe. It is evident that the circumferential arrangement is the better means of confining the enclosed air and preventing circulation of the same.

41. *Third.* There is a marked difference in the efficiency of coverings, depending upon the size of the pipe. Referring to Table No. 9, it appears that all the coverings on the 10-inch pipes were more efficient than the coverings on the 2-inch pipes at the same pressure. The efficiency of the Navy Brand was 82 per cent. on the 2-inch pipe and 88 per cent. on the 10-inch; that of the Magnesia, 84.2 per cent. on the 2-inch pipe and 89 per cent. on the 10-inch; and that of the Asbesto-Sponge Felt, 85.4 per cent. on the 2-inch pipe, and 90.5 per cent. on the 10-inch. There is some difference in thickness, which accounts for part of this difference; but taking the case of the Asbesto-Sponge Felt, 66 laminations on the 10-inch pipe, and 59 laminations on the 2-inch pipe, these thicknesses were very nearly the same, but still there is a difference of about 5 per cent. in the efficiency. The conclusion to be drawn from these facts is that to obtain the same efficiency, disregarding questions of cost, the smaller pipes should be covered with a greater thickness of material than the larger pipes. This conclusion is at variance with the existing practice of covering manufacturers, which seems to be to increase the thickness of the covering for larger pipes rather than to diminish it.

42. It would seem at first sight that a given thickness of covering applied to a pipe should save the same relative amount of condensation, whether the pipe be small or large, being proportional simply to the extent of the outside surface of the bare pipe; but, on second thought, it will be seen that the loss of heat is due solely to the radiation which occurs from the outside of the covering, whatever actions may be going on within the covering and between it and the surface of the pipe. If the temperature of the outside of the covering is the same on one pipe as on another (and this equality of temperature would be expected if the thickness of the material were the same, and the outside surfaces were of the same character in the two cases), the radiation would be proportional to the extent of the outside surface of the covering whatever the size of the pipe. The outside surface of the covering, with a given thickness of material, is much greater in proportion to the outside surface of the pipe when the pipe is of small diameter, than when it is of large diameter; and, consequently, the relative amount of radiation prevented by the covering, or efficiency, decreases as the diameter of the pipe diminishes. Referring to Table No. 10, it appears that the radiation of heat from the coverings based on the area of outside surface of the covering, that

is, the number of heat units lost per degree difference of temperature per square foot of outside surface per hour, is very nearly the same for the 10-inch pipes as for the 2-inch pipes; thus showing that the area of outside surface of the covering is the controlling factor in this matter rather than the outside surface of the bare pipe.

43. *Fourth.* The various coverings tested, as already explained, were not all of the same thickness. Of the low pressure 2-inch coverings, Asbestocel and Gast's Air Cell were slightly below the thickness of the other coverings. Of the 2-inch high-pressure coverings, the Asbesto-Sponge Felt, 48 laminations, and the Magnesia, were also slightly thinner than the others. Of the 10-inch coverings, Navy Brand was thicker and Watson's Imperial thinner than the Asbesto-Sponge Felt, 66 laminations, and Magnesia. The tests on the 10-inch pipes with the two thicknesses of Asbesto-Sponge Felt, furnished data for a rough determination of the effect of thickness alone on the efficiency. The number of heat units lost by radiation, according to the tests on these coverings, is inversely proportional to the thickness of the covering raised to the $\frac{5}{8}$th power. Applying a correction to all the results based on this showing, thereby reducing the results to the equivalent for 1-inch thickness, we may form some approximate conclusion as to the relative efficiencies, which would be obtained if the thickness was the same in all cases. Table 13 gives the deductions for the equivalent of 1-inch thickness worked out by this rule. They are the figures given in Table No. 6, multiplied in each case by the thickness of the covering in inches before application raised to the $\frac{5}{8}$th power.

44. *Fifth.* As regards the relative efficiencies of the high-pressure coverings and the low-pressure coverings, it appears from Table No. 9 that there is a marked difference throughout in favor of the high-pressure coverings. The average efficiency of the low-pressure coverings tried was 75.2 per cent., and of the high-pressure coverings, 84.6 per cent. The average efficiency of the high-pressure coverings, as appears in Table No. 11, when subjected to the same pressure, namely, 80 pounds, as that of the low-pressure coverings, is only a trifle less, being 84 per cent. The average cost of the high-pressure coverings at the end of five years' service, when subjected to a pressure of 80 pounds, taken on the same basis as the cost given in Table No. 8, is $14,693. The average cost of the low-pressure coverings at the end of five

years' service, as given in Table No. 8, is $18.525. It would appear, therefore, that as a matter of commercial economy, the low-pressure coverings, so-called, are not so well adapted to their purpose even on low-pressure pipes, as the high-pressure coverings on the same pipes; and the general conclusion justified by this comparison is that although a covering may be expensive in first cost, as most of the high-pressure coverings are compared with the low-pressure coverings (the first cost being nearly 70 per cent. more), the efficiency is so much greater and the corresponding cost of fuel required so much less (over one-third), that as a matter of investment, the high-pressure coverings are well worth their extra cost.

45. *Sixth.* The observations of the surface temperature of the coverings taken in connection with the results of the condensation tests, are interesting in showing that little value can be placed upon comparative indications of surface temperature as a measure of their relative efficiency. For example, in the high-pressure section, 2-inch pipes, the most efficient result in the prevention of condensation was secured by Asbesto-Sponge Hair Felt, 3 ply, and it would appear from this that the surface temperature of the covering ought to be relatively low. As a matter of fact, the surface temperature on this covering was higher than on either the Asbesto-Sponge Felt, 59 laminations, or the Magnesia applied to either of the two pipes, being an average of 203 on the Asbesto-Sponge Hair Felt, and from 195.3 to 196.9 on the other coverings mentioned. Likewise, the condensation tests showed that the Asbesto-Sponge Felt on Pipe No. 6 was more efficient as a non-conductor than Magnesia, applied to No. 7 pipe, and yet the surface temperatures of the coverings were exactly the same, being 196.9 in both cases. Again, in the case of the Asbesto-Sponge Felt covering on No. 12 pipe, the radiation from that covering condensed 10.84 pounds of steam per square foot of surface per hour, as against 14.34 pounds in the case of Navy Brand on Pipe No. 11, the former being 25 per cent. less than the latter. Although there was this marked difference in the actual amount of radiation, the surface temperature of the coverings showed but a slight difference, being 211 degrees in the case of the Asbesto-Sponge Felt and 224 degrees in the case of the Navy Brand.

46. *Seventh.* The tables giving the relative efficiencies of the various coverings expressed in cost of coal required to supply the

loss by radiation, and the total cost of the coverings at the end of the five-year period of service, speak for themselves. It is evident that the Asbesto-Sponge Hair Felt and Sponge Felt occupy the leading place on both sizes of pipes, which ever basis of comparison is used.

47. *Eighth.* In the matter of durability of the coverings, the test were not of sufficient length, and they were not made under the necessary conditions, to demonstrate this point. Actual services for a long period of time is the kind of test that would be required. Judging from the appearance of the coverings when they were removed none of them were lacking in respect to durability, and, if I mistake not, they have all been proved in actual service to be sufficiently durable to answer ordinary commercial requirements.

Between the moulded form of coverings and the fibrous coverings there are some notable points of difference which bear upon this question. The moulded coverings, as a class, contain a large proportion of material which in its natural state is a powder. This material, under the wear and tear due to vibration of pipes, blows, wear from persons walking on the coverings, or abrasions from other causes, has a constant tendency to resume its natural powdered state. To bind it firmly together, and so far as possible remove this tendency, asbestos fibre is mixed with the powder in suitable quantity to secure the degree of permanence desired. The fibres of asbestos are interwoven one with another, and they provide the tenacity required to prevent in a measure the disintegration of the otherwise granular mass. It is evident that the larger the proportion of fibre the less the tendency to disintegrate, and when the material is composed entirely of asbestos the best obtainable result as to permanence should be secured. In the construction of asbestos felted coverings and of others composed of asbestos paper, or sheets, the asbestos fibre predominates to a very large degree. These coverings must, therefore, take the lead over moulded coverings in the matter of permanence of structure. Especially is this true of Asbesto-Sponge Felted covering. Being composed simply of thin felted sheets laid one upon the other, this covering is compact and uniform in structure, and at the same time tough and pliable, and no kind of rough usage to which coverings are commonly subjected will cause its deterioration.

As to the durability of asbestos itself there is no question. It is almost indestructible either under the action of extremely high temperatures or under the action of steam, moisture, or water.

TABLE NO. 1.

DIMENSIONS OF PIPES.

Number designating pipe.	Inside diameter of pipe (nominal).	Length, center to center.	Length, shoulder to shoulder.	Circumference of pipe.	Total, surface ‡ including drip ends.	Net, surface from § shoulder to shoulder.
	Inches.	Feet.*	Feet.†	Feet.	Square feet.	Square feet.
1	2	100.21	99.54	.625	66.5	63.24
2	2	100.54	99.87	.627	65.57	63.64
3	2	100.67	100.00	.631	66.05	64.12
4	2	100.69	100.02	.628	65.77	63.84
5	2	100.58	99.91	.629	65.61	63.68
6	2	100.60	99.93	.628	67.04	63.78
7	2	100.57	99.90	.627	65.59	63.66
8	2	101.28	100.61	.628	66.14	64.21
9	2	101.60	100.93	.628	66.34	64.41
10	2	100.66	99.99	.628	65.75	63.82
11	10	35.583	34.671	2.821	109.78	97.81
12	..	35.330	34.418	2.821	109.07	97.10

* For 10-inch pipes end of cap to end of flange.
† Exclusive of center flange.
‡ Including also flanges and supplies for the 10-inch pipes.
§ Including couplings on 2-inch, but excluding center flanges on 10-inch pipes.

TABLE NO. 2.

DATA REGARDING COVERING.

NAME OF COVERING.	Number designating pipe.	Thickness before applying.	Circumference after applying.	Calculated distance outside of covering to outside of pipe.	Weight per section 36 inches long.	Area of outside surface.
		Inches.	Inches.	Inches.	Pounds.	Square feet.
80-pound Section, 2-inch Pipes.						
New York air cell	1	1	14.38-	1.09	3.22	119.25
Gast's air cell	2	11/16	13.92	1.02	3.77	115.85
Carey's moulded	3	1	14.10	1.04	5.77	117.50
Asbesto-sponge moulded	4	1	14.53	1.11	7.25	121.12
Asbestocel	5	⅞	14.00	1.02	5.10	116.59
150-pound Section, 2-inch Pipes.						
Asbesto-sponge felt, 59 lam	6	1⅛	15.18	1.21	6.34	126.61
Magnesia	7	1	14.30	1.08	3.17	119.08
Asbesto-sponge felt, 48 lam	8	1	14.77	1.15	6.00	123.85
Asbesto-sponge hair felt, 2-ply, corrugated	8	1⅛	15.09	1.20	4.32	126.47
Asbesto-sponge hair felt, 3 ply, plain	9	1⅛	15.23	1.22	5.54	128.08
Asbestos Navy Brand	10	1⅛	15.02	1.16	3.69	123.69
150-pound Section, 10-inch Pipes.						
Watson's Imperial	11	1	41.03	1.14	20.48	118.47
Asbestos Navy Brand	11	1½	43.67	1.56	12.60	126.17
Magnesia	12	1 3/16	42.50	1.37	17.88	121.91
Asbesto-sponge felt, 76 lam	12	1½	44.1	1.63	28.55	126.49
" " " 66 "	12	1 3/16	42.75	1.41	24.47	122.59

Note.—In all except moulded coverings the increased thickness before applying varies according as the layers are loose or tightly compressed.

TABLE No. 3.

COST OF COVERING.

NAME OF COVERING.	Net cost, per running foot.	Cost of applying, per running foot.	Total cost applied to pipe, per running foot.	First Cost of covering applied to 10,000 square feet of pipe surface.
2-inch Pipes.	Cents.	Cents.	Cents.	Dollars.
New York air cell	12.32	4	16.32	2,599
Gast's air cell	10.56	4	14.56	2,319
Carey's moulded	8.64	4	12.64	2,013
Asbesto-sponge moulded	8.64	4	12.64	2,013
Asbestocel	9.60	4	13.60	2,166
Asbesto-sponge felt, 59 lam	19.20	4	23.20	3,694
Magnesia	21.12	4	25.12	4,000
Asbesto-sponge felt, 48 lam	19.20	4	23.20	3,694
" " hair felt, 2-ply, corrugated	15.11	5	20.11	3,202
" " " " 3-ply, plain	18.89	5	23.89	3,804
Asbestos, Navy brand	18.24	4	22.24	3,541
10-inch Pipes.				
Watson's Imperial	36.00	5	41.00	1,453
Magnesia	66.00	5	71.00	2,517
Asbestos, Navy brand	62.70	5	67.70	2,400
Asbesto-sponge felt, 76 lam	73.30	5	78.30	2,776
" " " 66 lam	54.00	5	59.00	2,092

TABLE No. 4.

SUMMARY OF AVERAGE DIFFERENCES OF TEMPERATURE AND HOURLY CONDENSATIONS FOR ALL THE TESTS.

NAME OF COVERING.	No. of Pipe.	No. of Tests.	Difference of Temperature between Steam and Air. Degs.	Difference between Wet and Dry Bulb Thermometers. Degs.	Condensation per hour for 6-hour period. Gross pounds.
80-pound Section 2-inch Pipes.					
1. Asbestocel	5	20	263.0	5.1	13.77
2. Carey and sponge felt	1	4	267.4	5.1	14.17
3. Asbestocel	1	3	261.7	6.6	14.00
4. New York air cell	1	5	256.6	4.4	13.93
5. Asbesto-sponge moulded	1	2	263.2	5.0	14.41
6. Carey's moulded	3	25	261.9	5.2	14.53
7. Asbesto-sponge moulded	4	25	261.9	5.2	14.65
8. Gast's air cell	1	1	259.6	5.3	14.92
9. " " "	2	21	262.6	5.0	14.93
150-pound Section, 2-inch Pipes.					
10. Asbesto-sponge hair felt, 3-ply	9	8	303.5	5.9	10.58
11. " " " " 2-ply, corrugated	8	3	304.9	6.5	11.22
12. " " felt, 59 laminations	6	7	304.1	6.2	11.36
13. " " " 59 laminations	8	6	301.0	8.0	11.10
14. Magnesia	8	6	302.3	5.4	11.87
15. Asbesto-sponge, 48 laminations	8	2	294.0	3.8	11.71
16. Magnesia	7	24	300.6	6.2	11.86
17. Magnesia	6	5	300.9	8.0	12.35
18. Asbestos Navy brand	6	3	294.4	3.5	13.53
19. " " "	10	24	300.6	6.2	13.52
20. Asbesto-sponge hair felt, 2-ply	9	2	302.3	9.4	14.71
150-pound Section, 10-inch Pipes.					
21. Asbesto-sponge felt, 76 laminations	12	7	302.0	6.2	10.84
22. " " " 66 laminations	12	3	315.0	4.8	12.15
23. Magnesia	12	3	299.2	7.2	13.19
24. Asbestos Navy brand	11	6	298.4	6.0	14.34
25. Watson's imperial, 1 inch	11	5	303.0	6.3	15.92
Bare Pipes.					
26. 2-inch pipes, 80 pounds pressure	1–5	1 ea.	273.2	3.6	59.50
27. 2-inch pipes, 150 pounds pressure	6–10	1 ea.	305.2	6.7	74.81
28. 10-inch pipes, 150 pounds pressure	11–12	2 ea.	295.4	3.9	109.39
2-inch Pipes, 150-pound Section, at 80 pounds Pressure.					
29. Asbesto-sponge hair felt, 3-ply, plain	9	1	270.3	6.8	8.90
30. " " felt, 59 laminations	6	1	270.3	6.8	9.40
31. " " hair felt, 2-ply, corrugated	8	1	270.3	6.8	9.40
32. Magnesia	7	1	270.3	6.8	10.00
33. Asbestos Navy brand	10	1	270.3	6.8	11.20
10-inch Pipes, 150-pound Section, at 80 pounds Pressure.					
34. Asbesto-sponge felt, 76 laminations	12	1	268.7	6.8	8.70
35. Watson's imperial, 1 inch	11	1	268.7	6.8	13.80

TABLE No. 5.

SUMMARY OF NET CONDENSATIONS AND DEDUCTIONS.

NAME OF COVERING.	No. of Pipe.	No. of Tests.	Net surface, Bare pipe. Sq. ft.	Net condensation per hour for 6-hour period. Pounds.	Heat units lost per degree difference per hour per sq. ft. B. T. U.
80-pound Section, 2-inch Pipes.					
1. Asbestocel	5	20	63.68	13.47	.728
2. Carey and sponge felt	1	4	63.24	13.63	.730
3. Asbestocel	1	3	63.24	13.50	.739
4. New York air cell	1	5	63.24	13.43	.750
5. Asbesto-sponge moulded	1	2	63.24	13.91	.757
6. Carey's Moulded	3	25	64.12	14.23	.768
7. Asbesto-sponge moulded	4	25	63.84	14.35	.778
8. Gast's air cell	2	21	63.64	14.63	.793
9. " " "	1	1	63.24	14.42	.796
150-pound Section, 2-inch Pipes.					
10. Asbesto-sponge hair felt, 3-ply	9	8	64.41	10.22	.462
11. " " " " 2-ply, corugated	8	3	64.21	10.86	.490
12. " " felt, 59 laminations	6	7	63.78	10.76	.490
13. " " " 59 laminations	8	6	64.21	10.74	.491
14. Magnesia	8	6	64.21	11.51	.524
15. Asbesto-sponge felt, 48 laminations	8	2	64.21	11.35	.531
16. Magnesia	7	24	63.66	11.50	.531
17. Magnesia	6	5	63.78	11.75	.541
18. Asbestos Navy brand	10	24	63.82	13.16	.606
19. " " "	6	3	63.78	12.93	.608
20. Asbesto-sponge Hair-felt, 2-ply	9	2	64.41	14.35	.651
150-pound Section, 10-inch Pipes.					
21. Asbesto-sponge felt, 76 laminations	12	7	97.1	9.29	.280
22. " " " 66 laminations	12	3	97.1	10.60	.306
23. Magnesia	12	3	97.1	11.64	.354
24. Asbestos Navy brand	11	6	97.81	12.79	.387
25. Watson's Imperial, 1 inch	11	5	97.81	14.37	.428
Bare Pipes.					
26. 2-inch pipes, 80 pounds pressure	1–5	1 ea.	63.7	59.16	3.081
27. 2-inch pipes, 150 pounds pressure	6–10	1 ea.	63.98	74.40	3.336
28. 10-inch pipes, 150 pounds pressure	11–12	2 ea.	100.45	107.84	3.220
2-inch Pipes, 150-pound Section, at 80 pounds Pressure.					
29. Asbesto-sponge hair felt, 3-ply, plain	9	1	64.41	8.54	.445
30. " " felt, 59 laminations	6	1	63.78	8.80	.463
31. " " hair felt, 2-ply, corrugated	8	1	64.21	9.04	.472
32. Magnesia	7	1	63.66	9.64	.508
33. Asbestos Navy brand	10	1	63.82	10.84	.569
10-inch Pipes, 150-pound Section, at 80 pounds Pressure.					
34. Asbesto-sponge felt, 76 laminations	12	1	97.1	7.4	.257
35. Watson's Imperial, 1 inch	11	1	97.81	12.5	.431

TABLE No. 6.

FINAL DEDUCTIONS.

LOSS OF HEAT PER DEGREE DIFFERENCE OF TEMPERATURE BETWEEN STEAM AND AIR, PER SQUARE FOOT OF PIPE SURFACE PER HOUR.

Name of Covering.	British thermal units lost per degree per square foot per hour
80-pound Section, 2-inch Pipes.	
1. Asbestocel	.728
2. New York air cell	.750
3. Carey's moulded	.768
4. Asbesto-sponge moulded	.778
5. Gast's air cell	.793
150-pound Section, 2-inch Pipes.	
6. Asbesto-sponge hair felt, 3-ply, plain	.462
7. " " " " 2-ply, corrugated	.490
8. " " felt, 59 laminations	.490
9. " " " 48 "	.531
10. Magnesia	.531
11. Asbestos, Navy brand	.606
150-pound Section, 10-inch Pipes.	
12. Asbesto-sponge felt, 76 laminations	.280
13. " " " 66 "	.306
14. Magnesia	.354
15. Asbestos, Navy brand	.387
16. Watson's imperial, 1 inch thick	.428
Bare Pipes.	
17. 2-inch pipes, 80 pounds pressure	3.081
18. 2-inch pipes, 150 pounds pressure	3.366
19. 10-inch pipes, 150 pounds pressure	3.220

TABLE No. 7.

COAL CONSUMPTION FOR 10,000 SQUARE FEET OF SURFACE HEATED 365 DAYS PER YEAR, 24 HOURS PER DAY.

Name of Covering.	Coal of 10,000 B. T. U. heat value per year.	Cost of Coal at $4 per ton of 2,240 pounds.	Relative coal consumption, lowest being 100 per cent.
80-pound Section, 2-inch Pipes.	Tons.	Dollars.	Per Cent.
1. Asbestocel	750.5	3,002	100.0
2. New York air cell	773.2	3,093	103.1
3. Carey's moulded	791.8	3,167	105.6
4. Asbesto-sponge moulded	802.0	3,208	106.9
5. Gast's air cell	817.5	3,270	109.0
150-pound Section, 2-inch Pipes.			
6. Asbesto-sponge hair felt, 3-ply, plain	552.0	2,208	100.0
7. " " " felt, 2-ply corrugated	585.5	2,342	106.1
8. " " felt, 59 laminations	585.5	2,342	106.1
9. " " " 48 laminations	634.5	2,538	114.9
10. Magnesia	634.5	2,538	114.9
11. Asbestos Navy brand	724.2	2,897	131.2
150-pound Section, 10-inch Pipes.			
12. Asbesto-sponge felt, 76 laminations	334.5	1,338	100.0
13. " " " 66 "	365.7	1,463	109.3
14. Magnesia	423.0	1,692	126.5
15. Asbestos Navy brand	462.5	1,850	138.3
16. Watson's imperial, 1 inch thick	511.5	2,046	152.9
Bare Pipes.			
17. 2-inch pipes, 80 pounds pressure	3,176.5	12,706	......
18. 2-inch pipes, 150 pounds pressure	4,022.3	16,089	......
19. 10-inch pipes, 150 pounds pressure	3,848.0	15,392	......

TABLE No. 8.

FIVE-YEAR COST OF COVERINGS, INCLUDING COAL CONSUMPTION, FOR 10,000 SQUARE FEET OF SURFACE.

NAME OF COVERING.	Cost of coverings at the end of 5 years' continuous service, coal for each year's supply purchased at beginning of the year, interest on entire investment taken at 5 per cent. and compounded annually.	
80-pound Section, 2-inch Pipes.	Dollars.	Percentage.
1. Asbestocel	17,717	100.0
2. Carey's moulded	18,351	103.4
3. Asbesto-sponge moulded	18,556	104.7
4. New York air cell	18,714	105.6
5. Gast's air cell	19,249	108.6
150-pound Section, 2-inch Pipes.		
6. Asbesto-sponge hair felt, 2-ply, corrugated	15,712	100.0
7. " " " felt, 3-ply, plain	15,795	100.5
8. " " felt, 59 laminations	16,327	103.9
9. " " " 48 laminations	17,307	110.1
10. Magnesia	17,690	112.6
11. Asbestos Navy brand	18,911	120.4
150-pound Section 10-inch Pipes.		
12. Asbesto-sponge felt, 66 laminations	9,930	100.0
13. " " " 76 laminations	10,160	102.3
14 Magnesia	11,606	116.9
15. Watson's imperial, 1-inch thick	12,046	121.3
16. Asbestos Navy brand	12,250	123.4

TABLE No. 9.

EFFICIENCIES OF COVERINGS, REFERRED TO RADIATION FROM BARE PIPES.

NAME OF COVERING.	Efficiency referred to bare pipes, per cent.
80-pound Section, 2-inch Pipes.	
1. Asbestocel	76.4
2. New York air cell	75.7
3. Carey's moulded	75.0
4. Asbesto-sponge moulded	74.8
5. Gast's air cell	74.3
150-pound Section, 2-inch Pipes.	
6. Asbesto-sponge hair felt, 3-ply, plain	86.3
7. " " " " 2-ply, corrugated	85.4
8. " " felt, 59 laminations	85.4
9. " " " 48 "	84.2
10. Magnesia	84.2
11. Asbestos, Navy brand	82.0
150-pound Section, 10-inch Pipes.	
12. Asbesto-sponge felt, 76 laminations	91.3
13. " " " 66 "	90.5
14. Magnesia	89.0
15. Asbestos, navy brand	88.0
16. Watson's imperial, 1 inch thick	86.7
2-inch Pipes, 150-pound Section, at 80 Pounds Pressure.	
17. Asbesto-sponge hair felt, 3-ply, plain	85.4
18. " " felt, 59 laminations	85.0
19. " " hair felt, 2-ply, corrugated	84.7
20. Magnesia	83.5
21. Asbestos, Navy brand	81.5

TABLE No. 10.

COMPARISON OF 2-INCH AND 10-INCH COVERINGS ON BASIS OF LOSS OF HEAT PER SQUARE FOOT OF OUTSIDE SURFACE OF COVERING. 150 POUNDS PRESSURE.

NAME OF COVERING.	British thermal units per square foot of outside surface of covering per hour per degree difference of temperature between steam and outside air.	
Size of pipe	2-inch.	10-inch.
Asbesto-sponge felt, 59 laminations, 2-inch, 66 lam., 10-inch, 1.21 and 1.41	.247	.242
Keasbey & Mattison's magnesia, 1.08 and 1.37	.283	.282
Asbestos fire felt, navy brand, 1.16 and 1.56	.313	.300

TABLE No. 11.

COMPARISON OF EFFICIENCY OF COVERINGS AT 150 POUNDS AND 80 POUNDS PRESSURE ON SAME PIPES.

NAME OF COVERING.	Efficiency referred to bare pipes.	
	At 150 pounds.	At 80 pounds.
Asbesto-sponge hair felt, 3-ply, plain	86.3	85.4
" " felted, 59 laminations	85.4	85.0
" " hair felt, 2-ply, corrugated	85.4	84.7
Keasby & Mattison's Magnesia	84.2	83.5
Asbestos fire felt, Navy brand	82.0	81.5

TABLE No. 12.

TESTS WITH AND WITHOUT STEAM IN CIRCULATION.

		Pipe No. 1. Dead Steam.	Pipe No. 1. Steam in Circulation.	Pipe No. 6. Dead Steam.	Pipe No. 6. Steam in Circulation.
Date, October 3, 1901.					
1. Condition of Surface,		Bare.	Bare.	Bare.	Bare.
2. Duration	hrs.	2.	3.	3.	3.
3. Average Steam Pressure	lbs.	86.	85.8	151.4	149.
4. Average Temperature of Air	degs.	70.5	71.5	70.5	71.5
5. Total Condensed	lbs.	112.75	167.75	217.25	214.25
6. Condensation Per Hour	"	56.37	55.92	72.42	71.42
Date, October 16, 1901.					
1. Condition of Surface		Covered.	Covered.	Covered.	Covered.
2. Duration	hrs.	2.	4.	2.	4.
3. Average Steam Pressure	lbs.	81.2	79.7	148 7	144.4
4. Average Temperature of Air	degs.	61.4	63.2	63.	64.
5. Total Condensed	lbs.	28.5	55.	25.	49.5
6. Condensation Per Hour	"	14.25	13.75	12.5	12.37
Date, October 17, 1901.					
1. Condition of Surface		Covered.	Covered.	Covered.	Covered.
2. Duration	hrs.	3.	4.	3.	4.
3. Average Steam Pressure	lbs.	81.5	80.6	150.4	147.4
4. Average Temperature of Air	degs.	61.5	62.9	63.7	65.1
5. Total Condensed	lbs.	42.0	55.0	37.5	50.5
6. Condensed Per Hour	"	14.0	13.75	12.5	12.62

Steam passed through per hour, 298.8 lbs.

SUPPLEMENTARY TESTS.

48. The manufacturers of Watson's Imperial covering, when notified of the tests, made objections, stating that the covering of their make used on the 10-inch pipe was of less thickness than they recommended for high pressure work; and at their request, the writer conducted a supplementary test on No. 11 pipe, using thicker covering, and another test of 2-inch Watson's Imperial covering applied to No. 7 pipe. These coverings were sent from the manufactory especially for this purpose.

At the request, also, of the Nonpareil Cork Manufacturing Co., Bridgeport, Conn., samples of Nonpareil cork covering, which they sent from their factory, were also tested, one sample being applied to the No. 11 10-inch pipe, and one to the No. 7 2-inch pipe. In both cases these tests were made after the main part of the test apparatus had been removed, leaving only Nos. 6 and 7 pipes and Nos. 11 and 12 pipes. The methods of conducting these tests were in substantial accord with those of the previous tests, excepting as to duration and including the heating of the pipes and coverings from the beginning of the run. The leading data and results of these tests are given in Table No. 14.

The thickness of the Watson's Imperial 2-inch covering, before application to the pipe, was 1 inch, * and the calculated distance between the outside of the covering and the outside of the pipe after application, 1.23 inches. The thickness of the Watson's Imperial 10-inch covering, before application, was $1\frac{1}{4}$ inches,* and the distance from the outside of the covering to the outside of the pipe, after application, 1.46 inches. The thicknesses of the Nonpareil cork covering before and after application, for the 2-inch size, were respectively $1\frac{1}{8}$ inches and 1.15 inches, and those for the 10-inch size, respectively, $1\frac{3}{16}$ inches and 1.41 inches.

The tests were made under approximately 150 pounds pressure.

* See footnote of Table No. 2.

TABLE No. 13.

NAME OF COVERING.	Calculated British thermal units per degree per square foot per hour, assuming a thickness of 1 inch in all cases.
80-pound Section, 2-inch Pipes.	
Asbestocel	.67
New York air cell	.75
Gast's air cell	.761
Carey's moulded	.768
Asbesto-sponge moulded	.778
150-pound Section, 2-inch Pipes.	
Asbesto-sponge hair felt, 3-ply, plain	.497
" " " 2-ply, corrugated	.527
" felt, 59 laminations	.527
" " 48 "	.531
Magnesia	.531
Asbestos, navy brand	.652
150-pound Section, 10-inch Pipes.	
Asbesto-sponge felt, 66 laminations	.341
" " 76 "	.342
Magnesia	.394
Watson's imperial	.428
Asbestos, navy brand	.472

TABLE No. 14.

SUPPLEMENTARY TESTS OF WATSON'S IMPERIAL AND NONPAREIL CORK COVERINGS.

NAME OF COVERING.	B. T. U. lost per degree difference of temperature between steam and air, per square foot of outside surface of pipe, per hour.	Efficiency of covering referred to radiation from bare pipes.
2-inch Coverings.	B. T. U.	Per cent.
Watson's Imperial	.548	83.7
Nonpareil Cork	.512	84.9
10-inch Coverings.		
Watson's Imperial	.357	88.9
Nonpareil Cork	.294	90.9

DISCUSSION.

Mr. William W. Crosby.—It is an accepted fact that in any steam plant the special fittings and other surfaces not provided for by molded or sectional coverings form from 20 to 35 per cent. of the whole. Prof. C. L. Norton, of the Massachusetts Institute of Technology, alludes to this fact in the report of his tests on pipe coverings in no uncertain terms. The tests referred to in Mr. Barrus's paper do not take account of this fact, but consider only sectional covering. From a practical standpoint, therefore, the results of these tests cannot be taken as a guide in the solution of problems of covering in general. It is to be regretted that plastic coverings were not included, for commercially they are important.

It is noticed that the so-called low pressure used was 80 pounds per square inch. This is a rather high figure for low pressure, and does not give much idea of the action at 10 pounds to the square inch or less.

In Table 8 a period of five years is assumed as a basis for figuring costs. No account seems to be taken of the fact that some of these coverings contain organic matter, which subjects the coverings to the possibility of deterioration.

Referring to the first paragraph of the report, where mention is made of the object of the trials, it is stated that the tests were made at the Manhattan Railway Company's plant. It would be of interest to have it stated if these tests were made for the railway company, or not.

Prof. D. S. Jacobus.—I would like to present the results of tests which I made over a year ago on coverings for 2-inch pipes, compared with some figures obtained by Mr. Barrus.

If you will examine Table No. 9 of Mr. Barrus's paper you will find that he gives results which he calls "efficiencies referred to bare pipes"—by that he means the percentages of the heat radiated by the bare pipes, which is saved by placing the coverings on the pipes. Starting with the asbestocel covering, which Mr. Barrus tested at 80 pounds pressure, we find that he obtained an efficiency of 76.4 per cent. By my experiments it was 77.2 per cent. In his test with Gast's air cell covering at 80 pounds pressure he obtained 74.3 per cent. and I obtained 74.4 per cent. For asbesto-sponge felt, 59 laminations, he obtained 85 per cent. at 80 pounds pressure, and 85.4 at 150 pounds pressure, and for some of this covering having about the same number of laminations I made it 84.9 per cent. For the magnesia his results were 83.5 per cent. at 80 pounds pressure and 84.2 per cent. at 150 pounds pressure, and mine were 83.2 per cent. For asbestos navy brand he obtained 81.5 per cent. at 80 pounds pressure, and 82.0 per cent. at 150 pounds pressure, and my tests gave 83.2 per cent.

The asbesto-sponge hair felt was made up of hair felt with layers of asbestos. With the three-ply plain, Mr. Barrus obtained efficiencies of 85.4 per cent. at 80 pounds pressure, and 86.3 per cent. at 150 pounds pressure. With ordinary hair felt covering my tests gave 86 per cent. In addition to the coverings already referred to, I tested Johns asbestos fire-felt, which gave an efficiency of 73.1 per cent.; and a covering made of car-

bonized silk, of German manufacture, called "Remanit," which gave about the same results as hair felt.

The point which I wish to make is this: Here are tests by Mr. Barrus at 80 and 150 pounds steam pressure, while my tests were made at from 55 to 75 pounds pressure. Yet you will see that there is a close agreement between our results when compared on the efficiency basis just explained. The agreement is, to my mind, a remarkable one, considering the fact that the loss of heat is so readily influenced by air currents, and it appears that by obtaining the ratio in the way described the results are, to a certain extent, independent of air currents. A small draught of air will change the absolute results considerably, because the loss is made up of the direct radiation and that produced by the conductive action of the air. If the currents of air are slightly different for two sets of tests, the absolute results will vary, but if enough tests are made in each case, with the bare pipes, under the same conditions as the covered pipes, the efficiency ratio, as above deduced, will give results which are comparable where the pipes are of the same size.

My tests were of about four hours' duration. There were four pipes, and the positions of these pipes were interchanged after two hours of uniform running, and average results were obtained for the two periods. Mr. Barrus's tests were of a much longer duration than my own. The close agreement in the figures which we obtained shows that it is unnecessary to make tests of a longer duration than that shown, to give reliable results by the agreement of consecutive readings, which was the basis governing the adoption of the four-hour period in my work.

Mr. William Kent.—I think this is a very valuable series of experiments. I wish to call attention to a few things which might be gleaned from the report, and which Mr. Barrus might add to it. For the cost of allowing pipes to go uncovered, one figure, for 80 pounds pressure, gives $1.27 per square foot of pipe per year; another, for 150 pounds, $1.61. These are figures more easily remembered than the figures given for 10,000 square feet. Not only Professor Jacobus finds a remarkable uniformity between his results and Mr. Barrus's results, but Mr. Barrus finds a great uniformity between the worst of the coverings which he tried and the best. For 80 pounds pressure and 2-inch pipe, the efficiency in tests of five coverings ranges only

between 74.3 and 76.4 per cent.; for 150 pounds pressure on six samples of 2-inch pipe coverings, 82 to 86.3 per cent.; and for 150 pounds pressure on 10-inch pipe the range was, for five coverings, 86.7 to 91.3 per cent., which shows that we can get, by buying the best coverings in the market, anywhere from 74 to 86 per cent. of saving. I figure that the loss of $1.61 per square foot per year for bare 2-inch pipe at 150 pounds pressure would be reduced to 30 cents by the worst of these coverings, and to 22 cents by the best.

In regard to the statement made by one of the gentlemen whose discussion was read, as to the parties for whom these tests were made, I think those who visited Mr. Barrus's tests said that the tests were made under the auspices of the one particular company, and this was generally reported in New York. It is stated in the paper that the manufacturers of the coverings did not know that they were to be used for tests. Does this statement apply to that company as well as to the other manufacturers?

Prof. H. W. Spangler.—I would like to ask Mr. Barrus how he determined the temperature of the steam on the inside of his coil when a large quantity of steam was going through the coil. As we all know, Mr. Barrus is the originator of the calorimeter, which depends for its action on the fact that if you allow steam to pass through a nozzle the temperature is higher than that corresponding to the pressure on the low side. I understand in the dead test that the radiation from the header *B* and *C* in his figure was sufficient to reduce the temperature down to that corresponding to saturation. But I do not understand that when a large quantity of steam was going through the coils, that this was the case. I do not know any reason why the temperature in the coils from which these figures were deduced should not be a higher temperature than that corresponding to pressure, because, he says in his paper that he reduced the pressure from 150 to 80 pounds through a valve, and if he did, and any quantity of steam was going through that valve, I do not see why the effect on the low side was not considerably higher than the temperature corresponding to pressure. He says also that he made one test of saturation, and he found that the steam was practially dry. I understood this to be on the dead steam tests, and that, I think, is entirely to be understood from the fact that a small quantity of steam was going through, and therefore the

radiation from the headers was sufficient to reduce that to a temperature corresponding to pressure. But I do not see how it can be so in the other cases. If you look at the tables you will find that the results were always low, except in one case I think, which looks to me as though the temperature that he took as the temperature in the inside of his pipe, and the quantity of heat going through the pipe, were not correct, unless he had some way of measuring which I do not find in the paper.

Mr. George Dinkel.—I should like to ask Mr. Barrus how he accounted for the radiation from one covering, or from one pipe to another, in those tests. The pipes being rather close together, and in the same position at all times, with no provision, such as a shield, between them, they will radiate from one another. That is, taking the pipes 1, 2, 3 and 4 down, 1 will radiate to 2, or *vice versa*—2 to 3, 3 to 4, etc. I was fortunate enough to see those tests, and, as I remember very plainly, No. 1 at the top was under an open areaway, and exposed to a cold draught. I should like to know how that radiation was taken into account.

Mr. E. S. Farwell.—I was interested in this paper, as I had occasion not long ago to make a similar series of tests for the International Paper Company. The relative merits of the coverings as found by Mr. Barrus agree very closely with the results of our tests. I also found in our tests that the moisture varied from two-tenths to nine-tenths of 1 per cent. The apparatus was very similar to Mr. Barrus's; but between the separator and the point of delivery into the test pipe there was a throttling calorimeter. I assumed in these tests that the relative efficiencies of the pipe coverings would be the same when the steam was flowing as when the steam was in a quiescent state, which, I believe, is practically what Mr. Barrus has done; but I did not believe, and I am surprised at Mr. Barrus's conclusion, that the actual quantity of condensation would be the same. It seems to me that when steam is flowing through a pipe there will be a sort of rolling motion of the steam, carrying particles of moisture to the iron pipe. These particles will act more or less as a vehicle for carrying the heat of the steam to the pipe and delivering it to the iron, resulting in a more rapid transit of heat. I believe that this view is borne out by the tests which have been made on radiating surfaces, with the use of superheated steam, as compared with saturated or moist steam. I think it has been observed that with the superheated steam there is less transmis-

sion of heat, the cause of which is, as I understand it, the lack of small particles of water to carry heat to the iron of the pipe. If that be so, it would seem that we should expect a more rapid transmission of heat, a more rapid radiation, when steam is flowing and the moist particles do come in contact with the pipe more rapidly. As I read Mr. Barrus's paper, it seemed to me that he found in the two cases the condensation to be the same, but that in the one case when the steam was flowing there should have been added an undetermined amount of moisture, which was undoubtedly carried off in suspension by the steam issuing from the orifice. I do not gather from the paper that he attempted to determine how much, if any, moisture was carried off through that orifice. I presume that there was considerable.

*Mr. Barrus.**—In regard to Professor Spangler's question as to the character of the steam, I would say that a thermometer was placed in each header, and I never found any indication of superheating in either one. If there had been superheating, due to withdrawing steam through the valve, which reduces the pressure from 150 to 80 pounds, the thermometer in the 80-pound header would have shown it. It never showed any rise of temperature above the normal figure. The reason is this: The total quantity of steam passing at any time through this header was not much over 2 horse-power. The header was a 6-inch pipe. The pipe supplying the header was a 2-inch pipe. Now we have 2 horse-power of steam passing through a 2-inch pipe, and that is such a slow current that if there had been any superheating whatever, due to withdrawing, it would all have been dissipated by radiation.

There is one point about which I would like to speak in addition to what is given in the paper, and which is brought out very plainly in Table 7, which shows the advantages of applying covering to steam pipes, no matter what their kind may be. The cost of coal used in supplying the steam to 10,000 feet of pipe, covered with the least efficient of the coverings tested, is given as $2,070 for a period of one year of 365 days, 24 hours per day. When the pipes were bare, under the same circumstances the cost of fuel to keep them heated was $12,706 per year. Showing that by covering pipes there was a saving of

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* Author's closure, under the Rules.

$9,400 in a year. The cost of this covering, given in Table No. 3, is $2,319. Under those circumstances the covering would be paid for four times a year.

In making a final closure to this discussion, I will first take up Mr. Kent's remarks. In the opening sentences, Mr. Kent thinks it better to reduce the quantities given in Table No. 7, to the basis of 1 square foot of surface. As it is simply a matter of placing the decimal point in the required place, whether the basis is the 10,000 square feet of the paper or the unit of 1 square foot suggested, the addition recommended seems to me immaterial and unnecessary.

In reply to the last paragraph of Mr. Kent's discussion, it appears that he has given much closer attention to the reports of those who attended a public exhibition of my testing plant than to the text of the paper, so that he has become confused, and he puts a question which has no meaning. He asks something about the coverings mentioned in the paper, which were manufactured by one of the companies. There is no statement in the paper to indicate that any specified company had anything to do with the manufacture of the coverings tested, and, consequently, there is no foundation for such a question. It should be said, however, that the import of the question is already fully answered in Mr. Kent's own quotation from the paper, which reads as follows: "It is stated in the paper that the manufacturers of the coverings did not know they were to be used for tests." This statement, it will be observed, is not qualified in any respect, and it applies to one covering as much as to another. If, in commenting on it as he does, he intends to convey the impression that he doubts whether it states the fact, he may quite as justly claim that the whole paper is a fabrication from beginning to end.

Mr. Kent goes out of his way to tell the society what he has heard regarding the auspices under which the tests were made. I would say in regard to this that the paper makes no reference to this subject, although quite complete in all other respects. My silence on this one point was intentional, as I did not consider the matter of auspices had any bearing on the vital questions involved, these being purely of an engineering nature. Had they been otherwise, I should not have had the temerity to place a record of my work before the American Society of Mechanical Engineers.

Mr. Kent's remarks are nothing less than an attack upon the integrity and reliability of the work, and as such I cannot do otherwise than resent them. I am not unduly sensitive in the matter, for others who have no personal interest in the subject share my feelings. My first intention was to ignore them in the final closing, but on further consideration I will gratify Mr. Kent's curiosity so far as I can properly do so. The tests were not made under the auspices of any particular company, and the impression that they were, which Mr. Kent refers to, is erroneous. They were set on foot and paid for by a number of parties who wanted practical and reliable information on the subject, the only understanding being that the work should be wholly disinterested. Who these parties were is of no concern to any one but myself. It is enough to say that after the work had once been set on foot, my clients had no more to do with its policy or methods, or any other question of vital importance relating to it, than Mr. Kent himself.

In reply to Mr. Wm. W. Crosby's criticisms, I do not agree with his statement that it is an accepted fact that plastic coverings are used in every steam plant to the extent of from 20 per cent. to 35 per cent. of the whole. This statement is, to say the least, a great exaggeration of the facts, and in making it Mr. Crosby endeavors to unduly minimize the range of application of the results.

Mr. Crosby objects to the use of the term "low pressure" as applied to the 80-pound section of the apparatus. As the pressures tried were only two in number, one 80 pounds and one 150 pounds, this designation, as a means of comparison between the two, seems to me very appropriate. Under the circumstances, no one would think of the term "low pressure" having any reference to a pressure so low as 10 pounds, to which he refers.

The proportion of organic matter was so small in the coverings referred to that they could not be subject to material deterioration, even in five years' service. Experience with these particular coverings shows them to be exceedingly durable.

I am greatly obliged to Professor Jacobus for making the comparison which he does between the similar tests he made at Stevens' Institute and those reported in the paper. If any evidence were needed in support of the substantial reliability and impartiality of my work, it is furnished by this comparison.

Mr. Dinkel raises the question as to the effect of radiation of

one pipe to the next, there being no shields between them. I have made a similar series of experiments where provision was made for shielding one pipe from the radiation of the next pipe, and I found that there was no measurable difference produced by the introduction of the shields. If there is any correction to be made for this radiation, it is too small to be appreciable. So far as the pipe which was located under the open areaway is concerned, the experiments with the various coverings all applied to one pipe, as explained in the paper, demonstrate that the apparently unfavorable location of this pipe was in reality no detriment.

Mr. Farwell brings up an interesting point in relation to the effect of motion on the rate of condensation. I did not determine the amount of moisture passing off through the orifice when the steam was in motion. I can hardly agree with the inference, however, that considerable moisture passed away because the arrangement of the vent pipe which was attached to the top of the horizontal 2-inch test pipe was such that little if any water could have been picked up and carried over. Especially is this so when it is considered that the speed of the steam in the 2-inch pipe was not over 20 lineal feet per second. It has been found that steam will drop practically all its moisture in a horizontal pipe when the speed is several times this figure, and there is no reason to think that at the slow rate mentioned it would do otherwise.

No. 953.

MEMORIAL NOTICES OF MEMBERS DECEASED DURING THE YEAR.

SAMUEL W. SKINNER.

Mr. Skinner was born in Cincinnati, Ohio, on June 17, 1858, and died in the same city on May 20, 1901. His whole life and all his interests were bound up with that city, and it was for only the short periods of his college preparation at Exeter, N. H., and his college course at Harvard, from which he graduated in 1880, that he was away from his native town. After graduation he engaged in the business side of engineering, holding successively positions as Second Vice-President of the Blymyer Ice Machine Company of Cincinnati; President of the Blymyer Iron Works Company; Vice-President of the Cincinnati Bell Foundry Company; Vice-President of the Evansville Ice and Cold Storage Company, and his last connection was Secretary and Treasurer of the Cincinnati Shaper Company. He was a member of the Queen City and Optimist clubs, and chairman of a general committee appointed by the latter club on the question of smoke prevention in Cincinnati, which work engrossed him very much, and on which he wrote several articles. He was a member of the Loyal Legion through inheritance.

One of his strong characteristics was his interest in and genial remembrance of other men of all walks in life, whether his employees or old friends occupying positions of national importance; a man who had no enemies, whom even casual acquaintances liked, and who was loved by his friends in a way that falls to the lot of few.

Mr. Skinner was elected an Associate Member of the Society May 16, 1900.

JOSEPH HIRSCH.

By the usual formal communication from the related families, the death is announced of Honorary Member, Joseph Hirsch, Inspecteur Général Honoraire des Ponts et Chaussées, Professeur au Conservatoire National des Arts et Métiers, and distinguished author and investigator, as well as administrator.

Monsieur Hirsch was related to the great families of Mayer, Barra, Dreyfus, Dupont, and others well known among the old and most distinguished family stocks of France. His son, Monsieur Paul, is a member of the Garde Général des Eaux et Forêts; his nearest relatives are prominent in the Ponts et Chaussées, and the genius of the family is found in evidence on all sides in public works departments.

The widow, a son, and a married daughter survive, and one grandchild joins them in the family announcement of the decease of their distinguished relative.

Monsieur Hirsch, born in 1836 at Lyon (France), after passing through l'École Polytechnique and l'École des Ponts et Chaussées was appointed in 1860 Ingenieur au corps des Ponts et Chaussées.

From 1860 to 1869 he executed in this position a series of important works, among them being the canal of Houillères de la Sarre upon the German-French frontier, the dam of l'Isle Barbe on the Saône River near Lyon for converting that river into a canal, and of particular interest the great dam of the Mittersheim Reservoir for the feeding of the Houillères Canal, in which the level of the water was automatically regulated by a system of siphons. This installation procured for him the Cross of the Red Eagle of Prussia, and a gold medal at the Paris Exposition of 1867.

From 1869 to 1876 Monsieur Hirsch devoted himself to the study of metallurgy and forsook the public service. He directed the foundries and forges at Ars-sur-Moselle, and when these passed into German territory, he built to replace them, for Messrs. Dupont & Dreyfus, the blast furnaces and forges at Pompey, which have since become one of the most important plants of the group at Meurthe and Moselle.

After finishing this installation he established himself at Paris, and engaged in divers researches and experiments on steam machinery, for a memoir on which, published in *Annales des Ponts et Chaussées*, he received from the Minister of Public Works a gold medal. He also introduced to the French by a translation Thurston's "History of the Steam Engine."

From 1876 to 1898 he was Professor of Steam Engineering at l'École des Ponts et Chaussées, and from 1886 until his death Professor of Applied Mechanics at the Conservatoire des Arts et Métiers.

During this long period he was always intimately connected with questions of general mechanics and interior navigation and interested in experiments at Villète for smoke prevention.

As a member since 1886 of the Committee of Mechanic Arts of the Society for Encouragement of National Industry, he contributed to the bulletin of that society many reports and original studies made at his laboratory in the Conservatoire. Notable among these are the experiments on the burning of steam boilers, on heat engines other than steam, on tests of gas engines, etc. In interior navigation he made an extended study of elevators and inclined planes for boats of large dimensions. At the time of his sudden death, on the 22d of June, 1901, he was publishing in the *Revue de Mécanique* an important series of articles on recent experiments on a new type of steam engine.

His interest in the United States and in our prosperity, and especially our educational progress, was always great, and his faith in our institutions stronger than is usual among Europeans,

He has invariably been active in the work of preparation for the French international expositions, and has been the representative of his country, in most cases, at such expositions held in other countries; serving on the International Jury, and invariably with satisfaction to the government appointing him and to the exhibitors regarding whose products he was called upon to report. He united theoretical and practical knowledge with good judgment and an absolute fairness which made him an ideal judge and umpire.

Familiar from his earlier years of service with the work of General Morin and of his colleague and predecessor, Tresca, perhaps the two most famous investigators in engineering science that France has produced, Monsieur Hirsch was himself fully imbued with the spirit of research, and was able powerfully to promote and maintain that work at the Conservatoire and in other scientific schools and colleges of France. The administration of Colonel Laussedat, with which he has been identified for a generation past, has been thus made successful, and the traditions established by General Morin have been maintained by the association and coöperation of these able and earnest men.

His last letter to the writer of this inadequate notice, written during the last winter, conveys in impressive language his sense of the importance of the part played by our country in the drama of the nations, and expresses deep regret that we had not taken

a larger and more suitable part in the last International Exposition at Paris, as we thus ignored a great opportunity to make better known the skill of our mechanics and the magnitude and variety of our production in departments in which we might readily command a larger and more widely-extended market. He attributes this unfortunate oversight to our "politics," and his last words to this correspondent were:

"Un mot: la politique est plus funeste que la peste et le phylloxera!"

The literary and scientific work of Monsieur Hirsch is well illustrated in quality and character by, for example, his report on "Machines and the Apparatus of Mechanics," one of the reports of the International Jury at Paris, 1878 (Paris, "Ingenieur Nationale, MDCCCLXIII."), an 8vo of 600 pages, fully illustrated, which is a model in its department. His more strictly scientific and seriously professional work is illustrated in his "Discours sur les Machines à Vapeur," written in conjunction with M. Debize, 1885–1891, in which volumes are presented the course of l'École des Ponts et Chaussées, with which he was connected as professor, and of which he was an *Ingénieur en Chef*.

Monsieur Hirsch was a great man, a most learned man, a scientist, an able engineer, a fine teacher, a noble gentleman. As a professional colleague writes, immediately after learning of his unexpected decease:

"Savant, comblé de dignités, riche, très riche, entouré d'une belle famille, avec cela modeste et bon, il avait tout ce qu'il faut pour être heureux."

And no man ever earned more fully all the comfort and happiness which life can afford. His labors have made the whole world richer and better and wiser. His was a long professional life, full of good works.

He had been an officer of the Legion of Honor since August 14, 1900, and an Honorary Member of the Société Technique Impériale de Russie, and since 1889 he was an Honorary Member of the American Society of Mechanical Engineers.

JAMES F. LEWIS.

Mr. Lewis's first successes were as a member of the firm of Rand, Lewis & Rand, of Westfield, Mass., where he introduced methods of manufacture in the whip industry which have since

been adopted by all makers. Afterwards he was interested in the iron industries, both mining and manufacturing, and in 1881 was placed in charge of a blast furnace at Quinnemont, W. Va. In 1884 he became associated with the Rand interests in the Canadian Rand Drill Company, of which company he became president in 1890. Since 1895 he has had the active business management of the company, and has contributed very largely to its great success.

At the beginning of the Civil War Mr. Lewis enlisted in the Third Connecticut Volunteers, and fought at the battle of Bull Run, in which engagement he was wounded. He was always ready to do a service to another, and had therefore, deservedly, hosts of friends. He and the world were friends. He was a member of many other engineering, scientific, and social societies, as well as of the American Society of Mechanical Engineers, which he joined in 1887.

Mr. Lewis's death was the result of a somewhat protracted illness resulting from pneumonia, which attacked him while preparing for a Southern trip in search of better health. The end came at Boston on July 23, 1901.

EDWARD G. PARKHURST.

Mr. Parkhurst was born in Thompson, Conn., August 29, 1830. He was a prominent inventor of improvements in machinery and of automatic motions for machine tools, and also of devices for rapid-fire guns. His connection with the last-mentioned line of work dates from his connection with the Savage Arms Company, of Middletown, during the Civil War. Later he was in the employ of Pratt & Whitney, and made many improvements in their products. He was for many years assistant superintendent of their works. Since leaving them, some six years ago, he has been connected with the American Ordnance Company and with the Bethlehem Steel Company.

Among other inventions made by Mr. Parkhurst is the automatic rod feed for screw machines, which, by the movement of a single lever, first in one direction, then in the other, opens the jaws of the chuck, feeds up the stock, and closes the chuck, all while the machine is in motion.

Another recent improvement in the Krag-Jorgensen rifle was a five-cartridge magazine clip which is being tried by the United States Army in the Philippines.

Mr. Parkhurst was a man whom to know was to love. His musical and literary tastes, as well as his geniality and good-fellowship made him as much of an acquisition to social gatherings as did his ability and knowledge to those of a technical nature. He was one of the little band of charter members, rapidly growing smaller, of this Society, and was always interested in its meetings and welfare, though taking but little part in the discussions on the floor. He had served his home city of Hartford, Conn., as councillor and alderman, and was prominent in all movements making for good government. His death took place at his home July 31, 1901. A widow and one daughter survive him.

JAMES BARCLAY HENNEY.

James Barclay Henney, a member of the American Society of Mechanical Engineers since June 13, 1883, died suddenly of heart failure, November 3, 1901, at Manchester, N. H.

Mr. Henney was born at Plainfield, Conn., October 20, 1842, and was educated at the Plainfield Academy, afterwards pursuing mechanical studies under private instruction. He had a wide acquaintance among railroad men, East and West, and was prominent as a constructor of locomotives, many of his devices having been adopted in the standard designs for engines on the great trunk lines. His business life, with the exception of the last few years, was spent in connection with the Motive Power Departments of railroads, beginning with the Chicago and Alton, at Bloomington, Ill. From the Chicago and Alton he went to the Springfield and Illinois Southeastern, as General Foreman, then to the St. Louis, Kansas City and Northern, as Assistant Superintendent of Motive Power at the time Sir William Van Horn was General Manager. Soon after Mr. Van Horn was made General Manager of the Southern Minnesota he offered Mr. Henney the position of Superintendent of Motive Power, which office he held for several years, until the lease of that road by the Chicago, Milwaukee and St. Paul.

He next occupied the same position on the Wisconsin Central, and upon severing his connection with that road, came East to take charge of the Motive Power Department of the New York and New England, remaining with that company in that capacity during the receivership and presidency of the late Charles P. Clark.

From the New England road Mr. Henney went to Hartford, Conn., as Superintendent of an electric lighting and railway plant, and while so employed, was called to Schenectady as an inspector for the locomotive shops in that city. During that employment he went to South Africa to install there a number of locomotives ordered from the Schenectady Works by the Cape Colony Government, and remained until the engines were successfully tested.

His work gave great satisfaction to the South African authorities, and was followed by an additional order soon after his return home.

When the engine works at Manchester, N. H., were absorbed by the American Locomotive Company, he was sent there as Superintendent, and had been in that position but a week at the time of his death. A widow and three children, together with four brothers and one sister survive him. Of these, his brother, John Henney, is Superintendent of Motive Power of the New York, New Haven and Hartford Railroad Company, and a member of this Society.

Mr. Henney was devoted to his profession, a man of wide reading, and an accomplished mechanical engineer, with an enthusiastic relish for mechanical problems, in the solution of which he employed his time and talent with unwearying industry and patience. He was a man of fine administrative ability, loving order and honest work, and always insisting on it, just to the corporation employing him, and fair to the men employed. Perhaps the best commentary on his railroad work is found in the fact that in every instance he left his department better organized and more efficient than he found it.

Socially Mr. Henney was genial and attractive, devoted to his family and loyal to his friends; a man of the strictest integrity and honor, apt to judge others by the same high standard which he applied to himself. His career was one of distinguished usefulness, and his death leaves a vacancy not easily filled.

STEPHEN GREENE.

Stephen Greene was born in Hope Village, Scituate, R. I., September 27, 1851, and his earliest associations were with cotton manufacturing, which later, on extended lines, formed his life work, as his father, Alvin Greene, was both owner and manager of a cotton mill in which he took interest as a boy, thus

becoming familiar with all the operations and processes of the manufacture as carried on in that establishment. He prepared at Westerly for Brown University, from which he graduated in 1873, receiving the degree of Ph.B. He at once took up with the practice of civil engineering with various engineering offices in Providence, finally entering into partnership with Amos D. Lockwood, the most eminent mill engineer of his day. Mr. Lockwood's death made him the surviving partner of the engineering firm of Lockwood, Greene & Co., of Providence, which afterwards moved to Boston. As the head of this firm, he designed and supervised the building and equipment of a large number of cotton mills, and to him as much as to any one man was due the recent textile development of Southern mills on a large scale. He also took an active part in the construction of woollen and worsted mills and machine shops on lines of improved construction. In this work he had a large range of duties, beginning in many instances with a selection of the site, the design of the buildings, equipment of the machinery and arrangement of the power, in all of which he showed a thorough knowledge of details as well as of the purpose of the establishment as a whole; but his greatest ability was probably shown in the reorganization and extension of existing plants which had become superannuated by the depreciations of wear and tear and by subsequent mechanical inventions.

He was married in 1874, and leaves a widow and four sons. He had intimate relations with investors in cotton mill interests, and was a director in a large number of manufacturing establishments, also in several insurance companies and educational and benevolent institutions. He was a prominent member of the New England Cotton Manufacturers' Association, and joined the American Society of Mechanical Engineers May 15, 1889.

FREDERICK STIELTJES.

Frederick Stieltjes, a Member of the American Society of Mechanical Engineers, died at Amsterdam, Holland, on the 27th of December, 1901, at the early age of forty-four years, having been born at Hoorn, Holland, on the 17th of April, 1857. Mr. Stieltjes was first educated at the Elementary School in Hoorn, and afterwards continued his studies in Amsterdam, but was obliged to leave school when about fifteen years of age for a place in an office as a junior clerk. A few months afterwards

one of the members of the Amsterdam School Board, who had observed Stieltjes' diligence as a pupil, recommended him for a position in the business of the late Mr. H. J. G. Mynssen, a consulting engineer in Amsterdam. Here Stieltjes was in his element; he not only applied himself diligently to his business, but devoted all his leisure hours to the study of foreign languages, the principles of which he had learned in school, as is usual in Holland. He also acquired a thorough knowledge of bookkeeping; and, in fact, absorbed to an extraordinary degree all those general fundamental principles which make the successful business man. His position, however, did not satisfy his ambition, and he was constantly seeking new worlds to conquer. His abilities were so much appreciated by his employer, that he not only permitted him to transact business on his own account in his own time, but also assisted him in obtaining some agencies. By his extraordinary zeal, industry, and cleverness he succeeded to such an extent that Mr. Mynssen soon recognized that his business did not afford sufficient scope for Stieltjes' energy and ability, and they separated with the heartiest good wishes, and Stieltjes founded the firm of Fred. Stieltjes & Co.

In 1893, and again in 1899 he made a trip through the United States in order to visit the many American friends with whom he was in business relations, many of whom had already made his acquaintance when visiting Europe, and the friendships which he formed then continued till the day of his death.

As a number of American firms had given to Stieltjes the exclusive right to sell their goods on the Continent of Europe, he founded several "Stieltjes' Engineering Companies" in Brussels, Berlin, Copenhagen, Stockholm, Christiania, Vienna, Berne, Barcelona, and Paris. Almost all these companies, independent firms, although working in relation with the Amsterdam office, have achieved great success in the sale of American goods in Europe, and the managers of every one of them had the highest appreciation of his qualities, and were proud to call him a friend.

About fifteen years ago Stieltjes introduced the Worthington pumps into Holland, and succeeded to such an extent that the Worthington Pumping Engine Company founded a branch office under his control in Amsterdam, and their example was followed a few years later by the Sturtevant Engineering Company.

It can safely be asserted that no man did more for the introduction of American Engineering goods into Europe than Fred-

erick Stieltjes, and in the words of an American Government official who knew him well, "He was the best American in Holland."

Stieltjes was a self-made man and a born engineer. He very much regretted that he had not had in his early days the advantages of a scientific and technical education, but he was perfectly aware of his weak points, and was ever working without rest and with the most complete success to strengthen them.

He was interested in everything which tended to the best good of his city and his country, and his name was a synonym for all that is honorable and straightforward. His death is a sad loss for his widow, his friends, his firm, and his country.

WALTER V. FITCH.

Walter V. Fitch was born in Perry Township, Allen County, Ind., March 24, 1874, and died January 2, 1902. His father, mother, two brothers and three sisters survive him.

The most of his life was spent on the farm at home. Upon graduating from the district school he entered the Fort Wayne High School, and after two years' attendance there entered Purdue University in 1895, graduating from the mechanical department of that institution in 1899.

Since then he has followed his profession in Aurora, Ill.; Boston and Lynn, Mass.; and Chicago, Ill.

In 1900 he joined the American Society of Mechanical Engineers, of which Society he has since been an active member.

In August last he engaged with the Western Electric Company, of Chicago, with which company he was continuously employed until he was taken sick with pneumonia, December 15, 1901, resulting in his death.

CHARLES P. DEANE.

Mr. Charles P. Deane, the only son of George Howard and Maria Ward Deane, was born in Boston, January 20, 1845, of New England ancestry, of whom a large number were graduates of Harvard College in its early days. In 1849 the family moved to Cambridge, where Mr. Deane attended a private school, and later was graduated from the high school. After the financial crash of 1857 Mr. Deane's father made a change in

his business, and became associated with the mills at Ludlow, Mass., and his family took up their residence in Springfield, Mass., where Mr. Charles P. Deane made his home up to the time of his death.

At Springfield Mr. Deane continued his education at Williston Seminary, and later on at Brown University, from which, while he was not a graduate, he in later years received an honorary degree. On leaving college in 1865 he became associated with his father in the Ludlow Mills.

He always showed a markedly mechanical mind, and was very much interested in scientific investigation. In the sixties he and his father became interested in steam pumps, and Mr. Charles P. Deane with his alert and mechanical mind took out several patents on direct-acting steam pumps. In 1867 the well-known firm of the Deane Steam Pump Company, of Holyoke, Mass., which bears his name, was incorporated, and there Mr. Deane's efforts for said company have become widely and favorably known as the manufacturer of all kinds of pumping machinery. In this company Mr. Deane held an active position up to the time of his death. He was liked by all who came in contact with him, and was endowed with an unusually bright and active mind, warm heart, and generous nature.

As an engineer he stood very high in his profession, and was considered one of the foremost hydraulic and steam engineers in the country. He was a delightful companion at home and in business life, and was universally respected. Besides being a member of the American Society of Mechanical Engineers, he was also a member of other engineering societies and associations of a scientific character. His membership in this Society dated from April 7, 1880, his signature being on the register of the first annual meeting.

FRANCIS A. PRATT.

Francis Ashbury Pratt was born in Woodstock, Vt., February 15, 1827. He was of the English ancestry which early settled in New England, and inherited their sturdy qualities in full degree. His early years were spent in school and as an apprentice with Warren Aldrich. At twenty-one he entered the employ of the Gloucester (Mass.) Machine Works, where he remained for four years, then going to the Colt pistol works at Hartford,

where he became associated with Amos Whitney, his business associate for the rest of his life.

After two years at the Colt factory the two men went to the Phœnix Iron Works in the same city, Mr. Pratt becoming superintendent.

In 1860 the firm of Pratt & Whitney was founded, and started in a small way, but were burned out and obliged to start over, which they did in 1862 by taking in Monroe Stannard as full partner, giving the firm an entire cash capital of $3,600. From these wee beginnings the firm grew rapidly, and in 1869 was incorporated with $350,000 capital, Mr. Pratt being elected President, and Mr. Whitney General Superintendent. In 1898, by another reorganization, Mr. Whitney became President, and Mr. Pratt was made Consulting Engineer, a position which he soon relinquished, as he retired from business life.

The firm of which Mr. Pratt was a leading spirit was a pioneer in the improvement of machine tools and the introduction of the interchangeable system of manufacture now so universally used, and which has been so important a factor in carrying American machinery to the front. During the Civil War the firm taught the country this system for making firearms and invented the machinery for carrying it out; and after the close of the war they carried the same teaching to European armories and to the factories for other branches, such as watches and agricultural machinery in the United States.

In the course of this expansion Mr. Pratt made ten trips to Europe for securing orders and looking after installations, and was so successful that he brought home over two million dollars' worth of orders.

To Mr. Pratt's efforts also are largely due the establishment of a standard system of gauges which made the nationalization of the interchangeable system possible. And along the same line was the production of a gear-cutting machine which produced correct shapes of teeth, thus making fine gear work possible.

Mr. Pratt was always ready, even anxious to give to others credit for work well done, and was especially appreciative of the work done for the country by its technical schools.

His death occurred on February 10, 1902. He was a charter member of the Society, and was elected a Manager in 1880 and a Vice-President in 1881.

ROLAND GIBBS EWER.

R. G. Ewer, as he was more familiarly known, was born March 19, 1848, at Fairhaven, Mass., the son of Maj. B. Ewer, Jr., and Deborah Crowell Nye.

He attended the schools of his native village until 1864, when, his father having lost his life in the battle of Cold Harbor, he was apprenticed to a firm in the vicinity of Boston. In 1869 he came to Brooklyn to take charge of the machine shop of Charles Pratt's Oil Works, at Hunter's Point, now Long Island City. Enlarging their works, they removed to Brooklyn, the first plant being the present branch of the Standard Oil Company known as Charles Pratt's Oil Works of Brooklyn, Mr. Ewer remaining with them as constructing and consulting engineer until 1884.

In the meantime he with Mr. Henry R. Broad had established the Progressive Iron Works located in Brooklyn.

In the latter part of 1888 he was asked by the Pennsylvania Salt Manufacturing Company to superintend their works at Natrona, Pa., a position which he held until March of 1894, when he resigned to accept by solicitation of J. B. Ford the general management of an alkali plant located at Wyandotte, Mich. During Mr. Ewer's management it became and is now the Michigan Alkali Company. Differences arising in the company, he returned to Brooklyn in 1897, and again took up the management of the Progressive Iron Works. At the time of his death he was giving his attention to the developing of Texas oil. His love for his profession, aided by continual study, made him an engineer whose opinion was sought and considered authority.

He was a man of strong personal characteristics, which bound him strongly to those with whom he came in contact. He was a sincere friend, more ready to help others than to hold for himself; always anxious to give encouragement to those less fortunate than himself, or who, like him, were obliged to fight the battle of life without a father's help and advice. The shades of his home were never drawn at night, for "some lonely homesick boy, tempted almost beyond his strength may pass, and a glimpse of this happy home life may bring up memories and give him courage to strive on." This little instance shows the character of the man.

Mr. Ewer was one of the charter members of this Society, and was also a member of Franklin Institute.

He passed away after a short illness of pneumonia on February 21, 1902, leaving a wife and two children.

I have seen a tribute to the memory of his father, the ending of which is no less fitting for the son. "His life was gentle, and the elements so mixed in him, that nature might stand up and say to all the world, 'This was a man.'"

CHARLES H. NICOLL.

Charles H. Nicoll was descended from old English people who came to this country and settled when the English first wrested the possession of New York from the Dutch. He was born on Shelter Island, April 29, 1840, his father being Richard Floyd Nicoll, and his mother Rebecca Platt Nicoll. His father died in 1849, leaving him a boy nine years of age, who shortly after started to help in the earning of a livelihood for his mother and her five children, since he was the eldest son.

He afterwards learned the machinist trade, and also attended Cooper Institute, graduating from that institution.

In 1871 he went to Newark to become Chief Engineer of P. Ballantine & Sons' breweries, with the progress and development of which he was identified from that time until his death, which occurred February 27, 1902.

He was an expert in the construction of modern breweries, malt houses, elevators, and refrigerating plants, and generally in the mechanics which in any wise applied to the business of brewing and malting.

He was a member of the American Society of Mechanical Engineers since November 19, 1889, and a member of the Mecca Temple, Damascus Commandery, Kane Council, and Eureka Lodge of Newark, N. J.

BRYAN DONKIN.

On March 4th, last, the hand of death struck from our roll of members the name of Bryan Donkin, one of those few leaders in the profession who have united practical skill, business talent, and constructive ability with scientific learning, and who have constantly retained a firm hold upon technical and cultural information while promoting the highest work of the time in

the applied sciences of engineering and in the development of improved machinery and methods.

Mr. Donkin was a marked man at a very early period in his career, and a famous man much earlier than is usual even among men of genius. He came of a well-known family, distinguished for both ability and achievement. His grandfather, the first Bryan Donkin, only recently deceased, was the founder of the works at Bermondsey, in which this last Bryan learned his business. He was the inventor of a variety of devices for improving paper-making machinery, and constructed a famous dividing engine at a time when fine workmanship, as it would be to-day defined, was hardly known or even possible. He was a Fellow of the Royal Society and a friend of the great engineer, Farey, famous as an engineer and as an author of a standard treatise on the steam engine of Watt's time. The two men became partners in the Bermondsey firm.

Bryan Donkin, the subject of this sketch, was born in 1835, the oldest son of John Donkin, a brilliant but short-lived member of the Donkin family. He was educated at the University College, London, and in l'École Centrale in Paris. He completed his education by study and travel in Europe and in his own country. Later he served an apprenticeship with his grandfather's firm, thus acquiring that combination of the practical with the scientific side of his professional work which is so rare, yet so invaluable to the man capable of acquiring it and of employing it with success.

In 1859 he was sent to Russia to erect what was then the largest paper mill, and did his work well. In 1868 he was made a partner in the firm, and continued his connection with it for many years. About 1900 he, with Mr. Clench, organized a considerable engineering business at or near Chesterfield. The old firm has in recent years given up the manufacture of paper-making machinery and occupied itself with the construction of apparatus for gas making.

Mr. Donkin's work in experimental research in the field of applied science in engineering was begun in his first days of freedom from the trammels of the day's work. One of the earliest of compound stationary engines, designed by Farey, then recognized as a leading constructor, drove the machinery of the Bermondsey works. Donkin, following in the steps of his great masters, Hirn and Dwelshauvers-Dery, whom he always

delighted to honor, carried on an extensive and varied series of experiments on this engine. It is asserted, by those familiar with these experiments, that he, with Farey as his coadjutor, first proved by direct scientific determination the transformation of heat into work in the steam engine. He ascertained the quantity of heat thus disappearing by noting the difference in quantity of heat supplied from the boiler, and passing into the condenser, making due allowance, as accurately as was then practicable, for intermediate losses by conduction and radiation.

In his later years he devoted himself with his accustomed energy and earnestness to the investigation of the phenomena occurring within the steam cylinder, and invented his "Revealer," to reveal the behavior of the steam in its action within the cylinder during the working stroke. This subject had constant and enduring interest for him, and he never lost an opportunity either of securing new information, or of making it over to his professional comrades. With Professor Kennedy he studied experimentally the thermal flow and efficiencies of steam boilers, and secured a very valuable collection of new and useful data.

His latest work has been upon the gas engine, and his interest and enthusiasm regarding every aspect of applied thermodynamics led him to devote himself intensely, and probably to his own injury, to the various researches opening themselves to view as he pursued his investigations. His treatise, "The Gas Engine," published by Griffin & Co., contains the latest work of this great engineer, physicist, and thermodynamist.

A fairly long lifetime of good works, aggregating vastly more than is usually possible with the oldest in the profession, was recognized by the men of science of Great Britain and of other countries, as well as by the greatest minds of his own profession. He was made a member of the Royal Institution and of other scientific associations, of the British Institution of Civil Engineers, and of the American Society of Mechanical Engineers. The British Institution of Mechanical Engineers made him its Vice-President.

Mr. Donkin was not only a distinguished engineer and scientific investigator, an author of fame and a business man successful in his enterprises of whatever kind; he was a cultured, learned gentleman, an earnest man, a good friend, and a public-spirited citizen. A more sound and symmetrical character is rarely met.

His moral strength, his fine and cordial manner, his intellectual power, his great heart, and his unusual genius made him a marked man wherever he became known. The profession and the Society, as well as his friends and his country, have in his decease met with a loss which cannot be repaired. He was a member of this Society from November 30, 1892, until his death on March 4, 1902.

W. L. HOFFECKER.

Mr. Hoffecker was born in Beaver Meadows, Pa., on February 28, 1842. During his school years he was engaged for some time with civil engineers in the survey of the anthracite mines and the surrounding country for the Hazleton Coal Company. At the age of seventeen he entered the Lehigh Valley Railroad shops at Beaver Meadows, and at Weatherly under his father, who was Superintendent of Motive Power. Under the senior Hoffecker's direction the Weatherly shops were noted for their excellent work, and it was here that Mr. W. L. Hoffecker laid the foundation for his life's work as a railway mechanic. From Weatherly he went to the shops of the Pennsylvania Railroad at Altoona, where he served for four years in the position of erecting foreman. From Altoona he went to the Grant Locomotive Works as draftsman, which position he held for two years, and then was for four years with the Lehigh Coal and Navigation Company as Master Mechanic at White Haven. He left this position to engage in contracting on his own account, at the same time managing a planing mill at Hazleton, Pa.; but the attraction of the railway field was too strong, and in four years he returned to it as foreman in the Delaware, Lackawana and Western shops at Kingston. After four years in this position he was made Master Mechanic on the Pittsburgh and Western, in which position and as Master Mechanic for the Ohio and Mississippi and the Atchison, Topeka and Sante Fé he spent the next eight years.

At the end of that time, in 1877, a move was made eastward again, and he became Superintendent of Motive Power for the Central Railroad of New Jersey, which position he held until his resignation from it about four years ago. As he had accumulated ample means, he spent the remainder of his life in leisure and the enjoyment of a well-earned rest from arduous work, although he kept up his interest in engineering and railroad

matters, and did some consulting work until his death, which occurred on March 18, 1902. Mr. Hoffecker joined the Society in November, 1890.

THOMAS FORSAITH.

Members will regret to learn of the death of Mr. Thomas Forsaith, mechanical instructor and deputy-registrar of the South Australian School of Mines and Industries, which occurred on April 8th, at North Adelaide, South Australia. Mr. Forsaith was an enthusiast in his work, and by the capable and conscientious discharge of his duties he had won the confidence and respect, not only of the students under his control, but of the council, and of his fellow-instructors. He had a very large circle of friends, and every one who knew him was impressed by his high ideals, by his straightforwardness, and by his tireless industry. Although he had been in poor health for some time, and a year ago was stricken by a serious illness, Mr. Forsaith, with characteristic zeal, remained at his post almost to the last.

Mr. Forsaith was born in England about fifty-six years ago, but came to South Australia when quite a lad. His father established an ironworking business in this city, and with him Mr. Forsaith served his apprenticeship. In early life he assisted to fashion much of the ironwork of the seats in the Brougham Place Congregational Church. Subsequently he went to Mount Barker, where the late Hon. J. G. Ramsay was then the head of a flourishing foundry, and when the northern agricultural areas were opened up Mr. Forsaith, seeing an opportunity for widening his sphere of usefulness, removed to Laura, where he entered into partnership with Mr. Daniels in an implement factory. He took a prominent part in local affairs, and was an active member of the Baptist Church there. On relinquishing his connection with Laura, Mr. Forsaith returned to Adelaide, and became associated with Messrs. J. H. Horwood & Co., engineers, of Hindley Street, with whom he remained until, in 1899, he was appointed to the charge of the mechanical department of the School of Mines.

Mr. Forsaith's duties included the imparting of instruction in fitting and turning, building construction, carpentry, engine and boiler making and management, and mechanical drawing. He was a wonderful organizer, and the great interest which he

always took in the school resulted in a large number of students being attracted to his classes. On more than one occasion specimens of the skill of his students have been shown at public exhibitions in Adelaide or elsewhere, and they have invariably been greatly admired.

Mr. Forsaith was deservedly popular with every one connected with the establishment. He was Vice-President of the Association of Instructors connected with the school, and was the only local member of the American Society of Mechanical Engineers, which Society he joined in December, 1899. Although an extremely modest man, it was impossible for any one to be long in Mr. Forsaith's society without being impressed with the wide range of his knowledge and with the complete hold which his work had upon his heart. He was a Past Master of the Masonic craft, having gone through the chairs in Laura, and he was also associated with Odd Fellowship and with the Foresters' Society.

Mr. Forsaith leaves a widow, one son, and four daughters.

The School of Mines and Industries has voted to erect a memorial tablet to Mr. Forsaith in the department in which he labored so long and faithfully.

HENRY MORTON.

The name is one which needs no meed of praise or narrative of achievement. For thirty years it has stood as a synonym for all which is best in manhood and most notable in science, and has been famed throughout the world wherever technical ability and technical education are known. His life work has been the organization and conduct of Stevens Institute, which will ever be as much a monument to Dr. Morton as to the noted engineer whose name it bears.

Henry Morton was born December 11, 1836. He passed through the usual preparatory schooling, and entered the University of Pennsylvania, from which he graduated in 1857. After this he devoted much time to the liberal arts, and made a complete translation of the Rosetta stone, which was noted as a remarkable investigation. For a time the young man read law, but soon turned to the more congenial fields of chemistry and physics, and began to teach these subjects at the Episcopal Academy, using apparatus for his lectures made mostly by himself, and which soon brought him into prominence by its originality.

In 1863 he was appointed Professor of Chemistry in the Philadelphia Dental College, and the next year Secretary of Franklin Institute. In 1868 he went to the University of Pennsylvania in a temporary appointment to the chair of physics and chemistry, in which position he was so successful that a special chair of chemistry was created for him.

In 1869, when by the will of Edwin A. Stevens an "institution of learning" was to be founded, the attention of Mr. S. Bayard Dod, President of the Board of Trustees, was attracted by a series of lectures given by Professor Morton in aid of the Franklin Institute, and the conduct of the new enterprise was entrusted to him.

Of its success and the influence which his personality and wise judgment had toward producing it little need be said; the testimony of hundreds of grateful graduates bears witness to it. It has always been run within its means, even when in somewhat straitened circumstances, which is a tribute to the wise financial management of Dr. Morton, while his large-heartedness is shown by his contributions to the support of the Institute, which have amounted to $145,000. His ability as a patent expert, of which profession he was one of the most eminent members in the country, enabled him to thus gratify his benevolent instincts.

As a scientific investigator Dr. Morton was no less noted than as teacher and administrator, and the large number of degrees conferred upon him show the honor in which he was held. But he was not alone scientist, for in literary and theological fields he was noted as well, and verses from his pen were often seen in the current magazines.

His connection with the American Society of Mechanical Engineers, one of the many organizations to which he belonged, dated from April, 1880, he being one of the charter members, and a Vice-President from 1882–1884. His death occurred on May 9, 1902.

ROBERT B. READING.

Mr. Reading was born July 18, 1869, in Allendale, N. J., at the home of his grandfather, Mr. Stephen Cable, who was one of the honored and highly respected men of Bergen County.

His paternal grandfather was Richard A. Reading, for many years President of the Board of Fire Underwriters of the city of New York.

Mr. Robert Reading was born a mechanical engineer. His ambition from his earliest years was "to be an engineer." His amusement, his study, his work were in this line only. After leaving the Stevens Institute, when not twenty years old, he was placed in the shops of the Elevated Road, by the late lamented Colonel Hain, who saw in the young man rare ability. In a few months he was advanced and given charge of all repairs, with numbers of men to direct and control, winning the respect of his superiors and the devotion of his employees. Later on Mr. Edwin Gould applied to Colonel Hain for a man capable of taking charge of the factory at Passaic, N. J., of the Continental Match Company, and Mr. Reading was made, by Mr. Gould, Manager and Superintendent, which position he filled creditably and to Mr. Gould's satisfaction.

In 1897 Mr. Reading, becoming imbued with the popular excitement aroused by the wonderful stories from the North, and filled with the spirit of romance and ambition, gave up his position as manager for Mr. Gould at the Continental Match Company, and started for the Klondike, where he arrived just as the Yukon River was freezing up for the winter in late September. His trip there was attended with many hardships and narrow escapes, in which his railroading experience stood him in good stead.

In July, 1898, after nearly a year of struggles and privations, he left Dawson and returned to Skagway, introducing himself to Mr. F. H. Whiting, who was then General Manager of the White Pass and Yukon River Railroad. The latter was soon impressed with Mr. Reading's knowledge of locomotives and mechanical ability, almost immediately put him in charge of the round house and rolling stock, and that winter sent him East to superintend the construction of some locomotives which were being built for the company by the Baldwin Locomotive Works in Philadelphia. The next spring Mr. Reading accepted an offer as Master Mechanic of the White Pass and Yukon River Railroad, returning to Skagway early in the spring of 1899. He fulfilled his duties in this position with manifest ability and success, meeting all emergencies and difficulties with skill and courage. When, in the spring of the next year, a new management having taken the place of the old in the administration, he left again for the States, he did so to the deep regret of all the employees of the road, who assembled and gave him a farewell

banquet, and presented him with a beautiful token of remembrance. Mr. Reading then, through his friend, Mr. W. J. McCarroll, went to the Baldwin Locomotive Works in Philadelphia, where he was appointed to the position of Locomotive Engineer, taking charge of and delivering and putting into service some Pennsylvania Railroad engines then building; afterward taking charge of the same work on the Philadelphia and Reading, Chicago and Great Western, Denver and Rio Grande, Chicago and Alton, and other roads, proving himself to be a competent and reliable engineer, and making friends wherever duty called him.

In December, 1901, he was selected to make an extended trip on the Atchison, Topeka and Santa Fé Railway, stopping at each terminal point and spending several days giving lectures and instructing the engineers regarding the operation and care of the Baldwin compound locomotives, which were being so extensively used on that road. Returning to Philadelphia in May, 1902, Mr. Reading made a short trip to Norfolk, Va., during the Convention of the Brotherhood of Locomotive Engineers. His last trip was made to Pinetown, N. C., where he was sent to examine a locomotive built for the Washington and Plymouth Railroad. After spending a few days there and making a satisfactory report, he returned to Philadelphia, and proceeded to his home in New Jersey on leave of absence, having contracted a fever on this Southern trip, which proved to be typhoid, and of which he died June 16, 1902. During his short service with the Baldwin Locomotive Works of about two years, Mr. Reading gave entire satisfaction, and his early death is greatly lamented by his many friends.

Mr. Reading's kindly disposition made him friends wherever he went, and his devotion to his mother and aged grandmother, who still survive him, was unusual and touching. While not demonstrative, he was a true friend to those who won his liking, and his kindliness toward the world at large is shown by the fact that he was never known to speak ill of any one. He became a Junior Member of the Society in June, 1891.

JOHN BUTLER JOHNSON

Professor Johnson, whose untimely death as the result of a runaway accident at his summer home on Lake Michigan occurred on June 23, 1902, was an engineer whom the Society and

the world can ill afford to lose. His life was largely spent in teaching, but he had also found time for authorship on the subjects of his chosen specialties, and for practice of his profession of civil engineering.

He was born near Marlboro, O., June 11, 1850. After completing his preliminary schooling he drove home the lessons he had learned by imparting them to others in the country schools, and eventually became principal of the high school.

In 1874 he entered the University of Michigan, from which he graduated in 1878, afterward spending five years as civil engineer.

He was called to the chair of Civil Engineering in Washington University in 1883, and spent the next sixteen years in building up that department, finding meanwhile time to write "The Theory and Practice of Surveying," and, in connection with Messrs. Turneaure and Bryan, "Theory and Practice of Modern Framed Structures," and also later "The Materials of Construction" and "Engineering Contracts and Specifications," all of which have become standard professional works.

In 1899 Professor Johnson was called to the University of Wisconsin as Dean of the College of Engineering, which position he held at the time of his death.

In his social life Professor Johnson was no less active. He was a Trustee of the Unitarian Church in Madison and Superintendent of the Sunday-school, and was practically the founder of the Art Club of the same city. His energies were always at the service of any worthy public cause.

He was a member of the American Society of Civil Engineers, the Institution of Civil Engineers of Great Britain, the Western Society of Engineers, the American Society of Mechanical Engineers, which he joined in June, 1891, and a Fellow of the American Association for the Advancement of Science. Recently he had been actively associated with the committee on the proposed Carnegie Institue of Pittsburgh.

JOHN H. HALL.

Mr. Hall was born in Portland, Conn., March 24, 1849. His early education was finished at the Cheshire Episcopal Academy; following this he entered business in New York with Messrs. Sturgis, Bennett & Co., importers of tea and coffee, with which company he remained for five years; then returning to Port-

land and purchasing a large interest in the Pickering Governor Company. After the death of the president of this company he was elected to that position, and was also made President of the Brainard, Shaler & Hall Quarry Company, Portland, at about the same time.

In 1888 Mr. Hall was appointed General Manager of the Colt's Patent Fire Arms Manufacturing Company, in 1890 elected Vice-President, and in 1901, on the reorganization of the above-named company, was elected its President and also President of the Gatling Gun Company.

In politics he was a Democrat, and in 1895 and 1896 was State Senator for the First District.

Mr. Hall was a Director in the Phœnix Insurance Company, Phœnix Mutual Life Insurance Company, Hartford Bank, Portland First National Bank, and Trustee of the Dime Savings Bank.

Mr. Hall was a member of the American Society of Mechanical Engineers of New York, Engineers' Club, New York, Manhattan Club, New York, New York Athletic Club, New York, Larchmont, New Haven and Hartford Yacht Clubs, Metropolitan Club of Washington, and the Country Club of Farmington, Conn. He joined the Society as an Associate Member in November, 1883.

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